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The soils, flora, vegetation and vertebrate fauna of Chatham Island, Western Australia

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Abstract

The biological results of the first scientific survey of Chatham Island, of area 69 ha and maximum height 186 m, are presented. The two main soil types and two intermediate kinds are described. The island supports 46 vascular plant species (of which only 4 are alien), 4 species of lizards and breeding populations of the Little Penguin, Little and Flesh-footed Shearwaters, Welcome Swallow and Silvereye. A species of native rat occurs. The only known extant population in Western Australia of the fern *Asplenium obtusatum* occurs on the island.

Introduction

Between 11 and 22 May 1975 we visited Chatham Island in order to trap Silvereyes for genetic studies. Responsibility for the research carried out was as follows. Five mist-nets were operated for a total of 360 hours in a representative 4 ha area (IA) in which also a quantitative study of habitat structure and plant diversity was made (IA and JRW). Plant specimens were collected from this area as well as over the whole island and notes on the plant communities were made (IA). Soil profiles were dug at various sites and detailed descriptions were made (JRW). Several hours on two nights were spent noting seabirds coming ashore to roost (IA and JRW). This report presents annotated lists of the flora and vertebrate fauna, part of the quantitative vegetation survey, as well as an analysis of the soil types.

Physiography

Chatham Island (116°30'E, 35°02'S) lies west-southwest of Walpole, on the south coast of Western Australia, and has an area of 69 ha (calculated from aerial photograph). The island rises nearly perpendicularly from the sea to an elevation of 186 m near its southern end, and slopes gradually to the north. Seen from the east or west the island has a wedge-shaped appearance (Fig. 1). The island measures approximately 1.2 km by 1.0 km at its widest point. It lies 1.1 km from the mainland. The depth of the intervening strait is 37 to 46 m. The island was separated from the present mainland 11 000—12 000 years ago. To the immediate east and south of the island depths range from 46 to 66 m (Admiralty Chart No. 1934 and D. Beale pers. comm. 1975).

The island is a granite-gneiss dome, of a type which is common in Western Australia. The resistance of such domes causes them to stand out as bosses often forming headlands, islands or peaks inland. On the southern side and near the summit very extensive areas of bare rock occur (Figs. 2, 3). A small area of limestone cliffs is present in the northwest corner. The average annual rainfall is probably similar to that of Walpole, and would be 1 400-1 500 mm.

Suitable landing sites are in bays on the north and west sides, but landing is difficult at all times owing to the swell. We landed in the northern bay.

History

The island was named Cape Chatham by G. Vancouver on 26 September 1791, after the Earl of Chatham. Vancouver's ship reached no closer than about 20 km and with poor visibility the island must have appeared as a conspicuous cape. Flinders in 1801 established its insular nature. William Nairne Clarke in his epic voyage from King George Sound to Nornalup and beyond in 1841 found Chatham Island on 6 March to be full of 'Sooty Petrel' burrows. He also found fur seals there.

The island has received little interference from man, although a fire was noted in the 1960s (D. Beale pers. comm. 1975). Small cairns at and near the summit show that the island has been landed on this century, probably by fishermen.

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Figure 1.—View of Chatham Island from southwest.

Soils

There is only approximately 40% soil coverage on Chatham Island, most of the surface being bare rock. Thus, most of the soils are extremely shallow (0-40 cm) and overlie granite slabs and boulders. In the northeast sector, however, much deeper soils occur on the more gentle slopes and there has also been considerable movement of weathered parent material downslope. This sector also exhibits marked differences in soil type due to the small outcrop of limestone (Fig. 2).

With the exception of isolated pockets, mainly near the summit of the island, all the soils have been extensively burrowed by seabirds to depths of up to 90 cm. The resulting soil disturbance and faunal wastes have clearly had a marked effect on soil formation.

The soils of Chatham Island were surveyed over a two day period, initially by two non-randomized transects across the major vegetation study area and later by a series of non-randomized soil pits located throughout the remainder of the island. Each profile examined was described *in situ* but pH, colour (Munsell soil colour chart) and texture were determined in the laboratory. A total of 15 soil pits and approximately 10 shallow inspection pits were examined. A generalized map of soil types is shown in Fig. 2.

Soils overlying granite

Peats.—Chatham Island experiences cool, wet conditions during most of the year due to its geographical location and highly exposed position. These climatic conditions have undoubtedly assisted in the development of shallow peats over most of the rock surface. In the deeper pockets of soil there is slight profile development (Appendix) and in some parts of the northeast sector there is clear evidence of ironpan formation, especially towards the limestone outcrops. The degree of *in situ* rock weathering within and to the base of soil profiles varies markedly from site to site and is generally associated with joints and discrete boulders.

Generally, the soils have a reddish-black surface horizon containing much organic matter and plant litter, and with an acidic pH in the range 4.0-5.0. In the deeper, more developed soils, there is a slight increase in fine clay with depth and overall a decrease in the amount of semi-decomposed plant litter. Feathers and other organic detritus occur in burrows at any depth and tend to complicate the rather subtle soil changes between horizons. There is usually a decrease in pH with depth to values as low as 3.5.

Many of these soils have poor drainage and the shallower soils in particular have a mass of plant roots and impeded lateral water movement at the soil/rock interface.

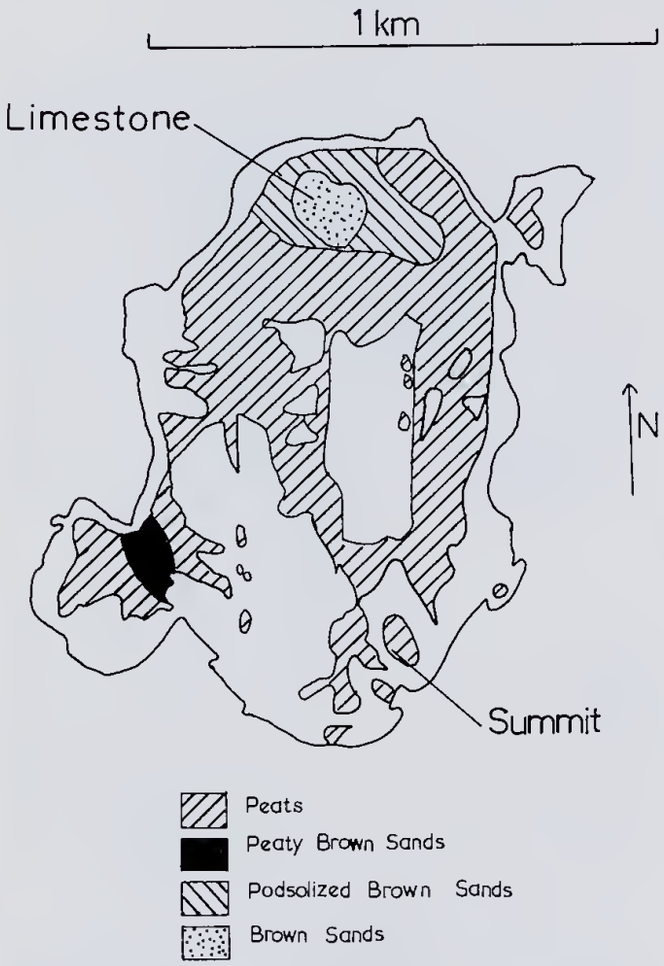

Figure 2.—The soils of Chatham Island. White areas represent (at this scale) bare rock.

Soils associated with limestone

Brown sands.—In the limestone area there are pockets of deep brown sandy soils occurring between exposed limestone outcrops. These soils show little horizon differentiation and are of neutral pH (6.5). Roots *(Rhagodia)* occur throughout the profile to depths of at least 60 cm but there is little surface accumulation of organic litter whether under *Poa* or *Rhagodia.*

Immediately downslope of the outcrops similar deep dark brown sands occur with a more marked brightening in colour (10 YR/4/6) at about 60 cm. These soils are alkaline (up to pH 7.9) with limestone fragments within the profile.

The brown sands are very freely drained.

Intermediate soils

Peaty brown sands.—This soil type occurs in a small area in the southwest sector, co-incident with the only area of *Atriplex* on the island (Fig. 3). It consists of a shallow brown sand (up to 60 cm) overlying granite, but with varying degrees of peaty surface horizon. Although there are no local outcrops of limestone, a large granite boulder nearby has remnant limestone attached to its underside. It is possible that this soil is a relic deep brown sand originally developed from limestone but subsequently truncated and now supporting peat formation in the surface horizon.

Podsolized brown sands.—This soil occurs in a transitional zone between the main limestone outcrops and the granite exposures. It contains a purplish-black (5 RP/1.7/1) iron-rich zone with varying degrees of induration and iron pan formation towards the interface with a bright brown (7.5 YR/5/8) underlying sand. The pH of these two horizons is extremely low (3.2-3.4) despite the occasional presence of both granite and limestone boulders mainly in the upper part of the profile.

Flora

In the following annotated checklist of vascular plant species, the percentage frequency of plant species found in 50 randomly distributed quadrats in the 4.0 ha plot is indicated. An asterisk denotes naturalized alien species.

ADIANTACEAE

Cheilanthes tenuifolia (Burm.f.) Sw. (2%). Widespread on thin soil over granite slabs.

ASPLENIACEAE

Asplenium obtusatum Forst.f. Small clumps (<1 m² area) of this vigorously growing fern were found in only two places at the south end. The first was under boulders c. 180 m above sea level and the second was in a valley at the south end c. 100 m above sea level. This record is the second for the State. It appears that the first record (on Breaksea Island, 1866, where collected by G. Maxwell) refers to a population that is now extinct as IA specifically searched for the species there in August 1975. This species occurs also in New South Wales, Victoria and Tasmania, where it is not a rare species (Wakefield 1955).

POACEAE

Poa australis R.Br. (74%). See Fig. 3 for distribution.
Sporobolus virginicus (L.) Kunth.
**Ehrharta longiflora* Sm. (16%).
**Aira caryophyllea* L.

CYPERACEAE

Carex preissii Nees. Found fruiting; only near sea level.
Scirpus nodosus Rottb.
Lepidosperma gladiatum Labill.

CENTROLEPIDACEAE

Centrolepis aff. *strigosa* (R.Br.) R. & S. Material is sterile. Rare; found on thin soil over granite slabs.

JUNCACEAE

Juncus pallidus R.Br. One clump only.

LILIACEAE

Chamaescilla corymbosa (R.Br.) F. Muell. (4%). Present as green fleshy projections from thin soil layer over granite.

ORCHIDACEAE

Cryptostylis ovata R.Br. Seen only in *Agonis marginata* and *Melaleuca microphylla* forest near summit.
Pterostylis vittata Lindl. Rare.

CHENOPODIACEAE

Rhagodia radiata Nees. See Fig. 3 for distribution. A few fruits noted.
Atriplex cinerea Poir. On west promontory only.
Threlkeldia diffusa R.Br. On limestone only.
Salicornia blackiana Ulbr. On west promontory only.

AIZOACEAE
Carpobrotus virescens (Haw.) Schwantes (8%). See Fig. 3 for distribution.

BRASSICACEAE
Lepidium foliosum Dcav. Amongst *Poa* tussocks.

CRASSULACEAE
Crassula macrantha (Hook.) Diels (2%).

PITTOSPORACEAE
Sollya heterophylla Lindl. In flower.

GERANIACEAE
Pelargonium australe Willd. (2%). On thin soil over granite, usually with *Cheilanthes* and *Trachymene*.
**Geranium molle* L.

RUTACEAE
Boronia alata Sm.
Chorilaena quercifolia Erdl. (6%).

RHAMNACEAE
Spyridium globulosum (Labill.) Benth. Rare. A few bushes near south end.

DILLENIACEAE
Hibbertia cuneiformis (Labill.) Gilg. In flower.

MYRTACEAE
Agonis marginata (Labill.) Schau. One of two tree species on island. Flowers noted. See Fig. 3 for distribution.
A. flexuosa (Spreng.) Schau. Rarely exceeding 1.5 m in height probably owing to the exposed positions in which it grows. See Fig. 3 for distribution.
Melaleuca microphylla Sm. The rarer of two tree species on island.
Thryptomene saxicola (A. Cunn.) Schau (6%). Flowers noted. Widespread, particularly around granite slabs.

HALORAGACEAE
Haloragodendron racemosum (Labill.) Orchard. Very few flowers. See Fig. 3 for distribution.

APIACEAE
Apium prostratum Vent. Near sea-level.
Trachymene anisocarpa (Turcz.) Burtt (52%). Widespread through tussockland and on thin soil over granite.

EPACRIDACEAE
Leucopogon parviflorus (Andr.) Lindl. Seen only in valley at south end.
Andersonia sprengelioides R.Br. See Fig. 3 for distribution.

PRIMULACEAE
Samolus repens (Forst.) Pers. Near sea-level.

LOBELIACEAE
Lobelia alata Labill. Flowers noted. Near sea-level only.

ASTERACEAE
Olearia axillaris (DC.) F. Muell. ex Benth. A remarkable form in which the leaf shape and arrangement resemble those of *Westringia dampieri*.
Senecio lautus Forst. f. ex Willd. (4%). Near sea-level and throughout tussockland.
Calocephalus brownii (Cass.) F. Muell.
Actinobole uliginosum (A. Gray) Eichler. A few flowers noted.
Gnaphalium luteo-album L.
Helichrysum bracteatum var. *albidum* DC. A few flowers noted.
**Hypochceris glabra* L. One rosette found.
sp. indet. (seedling) possibly *Parietaria debilis* Forst. f. (10%).
sp. indet. (seedling) (2%).
sp. indet. (seedling) (2%).

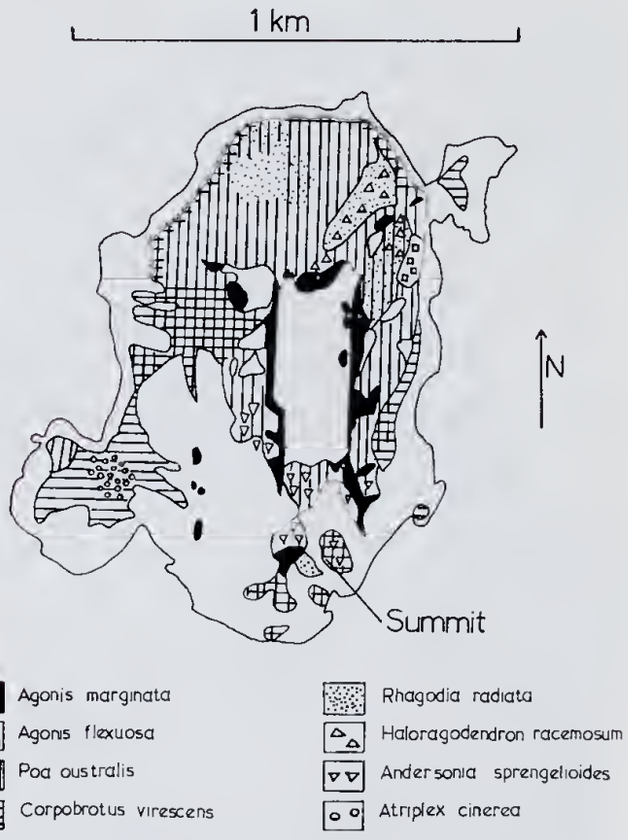

Figure 3.—Vegetation map of the island. White areas represent (at this scale) bare rock.

Vegetation

The main plant communities on Chatham Island are *Poa australis* tussock grassland, *Carpobrotus virescens* herbfield, *Rhagodia radiata* low closed-shrubland, *Agonis marginata* low closed-forest, and *Andersonia/Thryptomene/Cheilanthes* lithic complex. (See Fig. 3).

1. *Poa australis* tussock grassland. This community is the most extensive. Most cover is due to large tussocks (1 m high) of *Poa australis*, in between which *Trachymene, Senecio, Lepidium, Crassula, Ehrharta* and various small seedlings occur. On the western slopes of the island, especially at low altitudes, much *Carpobrotus* is present.

2. *Carpobrotus virescens* herbfield. This community is found on the two promontories and along the edges of the island. Near the summit *Carpobrotus* grows in windswept crevices containing very shallow soils. Associated genera are *Lobelia* (sea-level only), *Senecio, Sporobolus, Atriplex, Salicornia* (last two on west promontory only), *Samolus, Scirpus, Lepidosperma* and *Cheilanthes* (this last around rock slabs away from sea-level).

3. *Rhagodia radiata* low closed-shrubland. Near the limestone cliffs this species forms almost pure stands, with height not exceeding 1 m. Elsewhere *Haloragodendron* becomes codominant. In the valley at the south side *Apium, Boronia, Hibbertia, Chorliaena* and *Olearia*, amongst others, occur with *Rhagodia*.

4. *Agonis marginata* low closed-forest. Small stands of this species occur only in crevices with deep soil, where they are stunted. In valleys edged by near vertical granite slopes the species reaches 6 m. Considerable runoff must ensue from such places. Associated shrubs are *Melaleuca, Hibbertia, Chorilaena* and *Thryptomene.*

5. *Andersonia/Thryptomene/Cheilanthes* lithic complex. "Lithic" refers to the habitat of these plant species; they occur in thin layers of soil over granite or in small soil-filled joint lines in granite. On the plateau around the summit the first species occurs in cushion-like form and *Thryptomene* is a windblown bush no higher than 30 cm. *Thryptomene* occurs with *Cheilanthes* elsewhere around slabs of granite or on thin soils over granite over most of the island.

Vertebrate fauna

Amphibians

None were noted. Tadpoles were specifically searched for in the many pools of rainwater on the plateau leading to the summit.

Reptiles

Four species of lizards were noted. Snakes are absent.

Phyllodactylus marmoratus. Common under slabs of exfoliated granite.

Ctenotus labillardieri. One was found in soil under a *Poa* tussock.

Hemiergis peronii. Four were found under *Poa* tussocks.

Egernia kingii. The most abundant lizard species. It was found from sea level to summit excluding large expanses of rock devoid of pockets of vegetation or slabs. All specimens were black with prominent yellow markings.

Birds

Eudyptula minor, Little Penguin. Very common and found along all accessible parts of the coast (i.e. the north and west parts) in *Carpobrotus* and *Poa.* They were recorded as coming ashore 45 minutes after nightfall and leaving about 45 minutes before first light.

Diomedea melanophris, Black-browed Albatross. Two were seen offshore near the west and north sides respectively.

Puffinus assimilis, Little Shearwater. Only a few were seen, above the campsite amongst *Poa* tussocks. Only one skull was found.

P. carneipes, Flesh-footed Shearwater. This presumably is the 'large Sooty Petrel' found on the island in 1841 by Nairne Clarke. For the time of the year, the birds were surprisingly common. On a walk around the northern parts of the island one night we saw one adult every 15-30 m. No chicks were seen but during the day noises from underground were attributed to this species. Dozens of skulls were picked up over the island.

Sula bassana, Gannet. Three followed the boat as we approached the island.

Ardea novaehollandiae, White-faced Heron. One, presumed vagrant, was seen most days around the island.

Heliaeetus leucogaster, White-breasted Sea-eagle. One pair was seen most days, but they were never seen perched. No nest was found.

?Falco peregrinus, Peregrine Falcon. On 21 May one bird was seen briefly near the northern end, and IA's field notes are 'One falcon with black head; larger than Kestrel but smaller than Brown Falcon'.

Falco cenchroides, Kestrel. One pair was present. One bird was seen perched on an inaccessible ledge once; no nests were found.

Haematopus fuliginosus, Sooty Oystercatcher. Foraged on the more gentle granite slopes leading into the sea. Usually two or three birds were visible from the campsite. The maximum number of birds seen together was five.

Larus novaehollandiae, Silver Gull. Occasionally present at the campsite. Maximum number seen was 20. There was no evidence of breeding.

Sterna bergii, Crested Tern. One was seen fishing off the landing place on 17 May.

Dacelo novaeguinae, Kookaburra. One bird, presumed vagrant, was heard and seen in *Agonis marginata* scrub on 19 May at an altitude of c. 100 m.

Hirundo neoxena, Welcome Swallow. Common. Maximum number of birds seen at one time was 35. Two old nests were found in a cave on western side of island. The very spacious cave on the eastern side, which is unfortunately inaccessible, probably contains many nests as Swallows were seen to fly in and out of the cave.

Petroica multicolor, Scarlet Robin. One male, presumed vagrant, was netted, banded and released on 12 May.

Zosterops gouldi, Silvereye. Common over the whole of the island, but mostly seen in *Rhagodia* bushes. However few fruits were available so the birds were probably mainly eating insects. One hundred and thirty-two feeding actions were recorded, distributed as follows: 68% on *Rhagodia* leaves, 23% on *Haloragodendron* leaves and 9% amongst foliage or flowers of *Agonis marginata.* Thirty-four birds were netted, banded and released. An old nest was found in an *Olearia* bush, 1 m from the ground, at an altitude of c. 100 m.

Mammals

Rattus fuscipes. These were common around the boulders near the campsite, but none were noticed elsewhere. Several drowned in a bucket of water and were donated to the Western Australian Museum.

No mice, rabbits, goats, macropods or seals were noted. Fur seals occurred on the island in the past (Nairne Clark 1841; Cumpston 1970, p. 91). Seals are occasionally recorded at Windy harbour, 50 km northwest of Chatham Island (D. Beale, pers. comm. 1975).

Discussion

Despite the shallow nature of the soils on Chatham Island some interesting aspects of soil formation can be observed. The dominant climatic influence is undoubtedly a cool moist condition prevailing for most of the year. This condition is due both to rapid surface runoff from bare rock surfaces on the island and to the exposed position of the island.

In general there is little correlation between vegetation boundaries and soil distribution. There would probably be better correlation on the mainland. On Chatham Island, virtually all soils are so disturbed by the burrowing habits of fauna that effects of vegetation on soil formation are minimized. Although no chemical analyses were performed on the soils it is predicted that their nutrient status will be relatively high due to excreta and other faunal wastes deposited in and around burrows.

The most recent and detailed soil survey close to Chatham Island is that of McArthur and Clifton (1975) in the Pemberton-Mt. Chudalup region, located about 30 km to the northwest on the mainland. The peats on the island are probably representative of the *Chudalup association,* whereas the other soils discussed clearly belong to the *d'Entrecasteaux association.*

The flora and vertebrate fauna of Chatham Island are certainly depauperate, but no exact figures can be given because the plants and animals occurring on the immediate adjacent mainland have not been documented. In view of the exposed nature of the island, the absence of eucalypts is not surprising. During the last glacial when sea-levels were 100 m lower than at present, Chatham Island would have been merely a prominent hill about 25 km from the ocean. At present Mt. Chudalup (185 m high) lies close behind Windy Harbour and the deep red loams around it support karri *(Eucalyptus diversicolor)* forest with its characteristic suite of plant species. Thus karri would conceivably have grown around Chatham Island on areas now covered by the sea. It is likely that Yate *(Eucalyptus cornuta)* and Bullich *(E. megacarpa)* occurred on the island.

The absence of various sea birds, in particular *Pterodroma macroptera* (Great-winged Petrel) and *Larus pacificus* (Pacific Gull) is remarkable. The absence of the former is interesting. On Eclipse Island (near Albany) in April 1975 (where two migratory seabirds, the Flesh-footed Shearwater and the Great-winged Petrel, occur) adult Shearwaters had ceased visiting the island. The Petrels had first arrived in March. On Chatham Island some adult Shearwaters were still visiting the island during May. On Sandy Island (50 km northwest of Chatham Island) Flesh-footed Shearwaters occur without *Pterodroma* and adults were noted by IA returning at night as late as April 1976. These facts seem to indicate a negative interaction, perhaps mediated through availability of burrowing space, between the two species on Eclipse Island.

The Cape Barren Goose, *Cereopsis novaehollandiae,* probably occurred on Chatham Island in the past as it formerly ranged as far west as Cape Leeuwin prior to the arrival of sealers and fishermen. Certainly the island appears suitable to support three or four pairs. It may be feasible to stock the island with several pairs from the Archipelago of the Recherche.

As Pied Cormorants are absent from the coastline near Chatham Island no trampling of the vegetation on the island is evident. Burrowing species of seabirds (Little Penguin, both Shearwater species) disturb the soil and manure it (Gillham 1963), and a peculiar vegetation pattern on the north side of the island may reflect past deleterious influences by the burrowing seabirds. Amongst the *Poa* tussockland there is a large strip of dead *Poa,* running from near sea-level to a height of c. 100 m. There was no evidence that this had resulted from fire.

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Appendix

Peat with profile development (Site No. 5)

Aspect: 330°.

Slope: 10°.

Height: 100 m.

Rock type: granite.

Vegetation: *Agonis marginata, Rhagodia, Boronia, Olearia, Chorilaena, Melaleuca microphylla.*

1. 0-2 cm Reddish black (7.5 R/1.7/1); loamy texture containing sand and plant litter; loose structure; gradual change to
2. 2-12 cm Reddish black (5 R/1.7/1); silty loam texture with sand grains; gradual change to
3. 12-25 cm Reddish black (2.5YR/1.7/1); sandy loam with occasional boulders; loose structure; gradual change to
4. 25-45 cm Dark reddish brown (7.5YR/3/2); indurated gravelly loam; gradual change to unweathered granite.
   (a) pH 5.30 in horizon 1 with gradual increase to pH 5.55 in horizon 4.
   (b) Increase in fine clay with depth.

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The flora and fauna of Dirk Hartog Island, Western Australia

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Abstract

Dirk Hartog Island (62 000 ha), which lies off Shark Bay, Western Australia, between 25°30'S and 26°15'S, has been visited and studied by a succession of visitors since 1616. It consists of Quaternary Tamala Eolianite which forms rugged cliffs along much of the coast. The rainfall averages 313 mm, falling mostly in winter, while average temperatures range from 11-21°C (winter) to 22-32°C (summer).

There are five vegetation types: tall open-heath; low closed/open-heath with hummock grasses; low very open-heath; hummock grassland; and low open-shrubland. The known indigenous flora totals 258 species in 167 genera of 67 families. Of the named species, 77 are South Western, 61 Eremean and 102 common to both. The island is floristically transitional between the South West and Eremean Botanical Provinces but with a leaning to the South West. Thirty six species, mostly of European origin, have become naturalised.

Two species of macropod marsupials, *Lagostrophus fasciatus* and *Bettongia lesueur*, once occurred on Dirk Hartog but are now extinct. Two species of rodents, *Pseudomys albocinereus* and *P. hermannsburgensis* are present although not previously reported. Cats, goats and the House Mouse have become feral. Some 84 species of birds have been recorded by a number of visitors over the years. Most have wide-ranging distributions but a few southern species occur here at or near the northern limit of their range. Of especial interest is the Black-and-white Wren *(Malurus leucopterus)* which is restricted to Dirk Hartog and Barrow Islands. Twenty-seven species of terrestrial reptiles have been collected. Most are typical of the warmer and drier parts of southern-Western Australia.

Introduction

Dirk Hartog Island, the westernmost part of Australia, is a large island of about 62 000 ha which encloses the western side of Shark Bay, Western Australia (Fig. 1).

The first recorded landing by a European in Australia is that of the Dutchman Dirk Hartog at Cape Inscription, the northern tip of the island, in 1616 (Flinders 1814). Other early visitors were Vlaming in 1697 (Flinders 1814), William Dampier in 1699 (Dampier 1729), the Baudin expedition in 1801 (Péron 1807, Baudin 1974), Freycinet in 1818 (Quoy and Gaimard 1824), King and Cunningham in 1821 (King 1827) and Grey in 1839 (Grey 1841).

More recent visitors who have reported on aspects of the biology of the island include T. Carter in 1916 (Carter 1917) and 1922 (Carter 1923), F. Lawson Whitlock in 1918 and 1920 (Whitlock 1921), E. Ashby in 1927 (Ashby 1929), a group of students from Wesley College in 1967 (Sedgwick 1967, 1968), B. A. and A. G. Wells in 1973 (Wells and Wells 1974) and J. S. Beard in 1974 (Beard 1976). Most of the recent reports concentrate on birds and give only brief reference to other animals or plants. An exception is the description and map of the vegetation by Beard (Beard 1976).

Since 1899 Dirk Hartog Island has been held under pastoral lease as a sheep station. The whole island is leased except for 81 ha of freehold land and three small reserves at the northern tip containing the lighthouse and inscription posts (Reserve Nos. A12715, 14918 and 11634).

In 1972, the present lessee, Sir Thomas Wardle, invited the authors to visit the island and make an inspection.

The first visit took place from 2 to 8 September 1972. Personnel were A. S. George (Western Australian Herbarium) T. Evans and A. A. Burbidge (Western Australian Wildlife Research

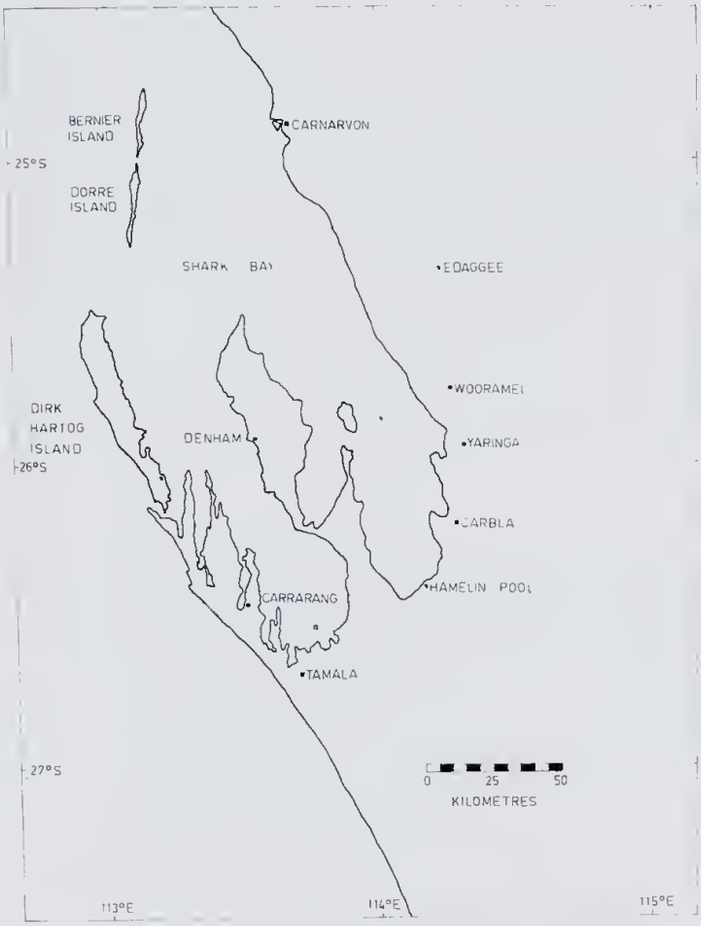

Figure 1.—Map of the Shark Bay area.

Centre). During this visit as much of the island as possible was traversed, using station tracks. In the daytime plants and animals were collected and observations were made on birds. Much time was spent searching for evidence of native mammals, such as tracks, droppings and skeletal remains. At dusk and after dark, spotlight traverses were carried out by vehicle and on foot. Traps were set for small mammals at various localities. The traps used were Elliott live traps (32 cm x 10 cm x 8 cm) and metal break-back traps.

Further visits which have been made to the island by staff of the Wildlife Research Centre have resulted in additional information. In April 1974 further small-mammal trapping and general collecting was carried out by W. K. Youngson.

Physical description

Dirk Hartog Island is about 79 km long and a maximum of 11 km wide with the long axis aligned 340°. The southern end (Cape Ransonnet) is separated from the mainland by South Passage which at its narrowest is about 2 km wide (Fig. 2).

Geologically the island is made up of Quaternary (probably Pleistocene) Tamala Eolianite (Logan *et al.* 1970). The geology of Bernier and Dorre Islands and the Edel Peninsula is similar but Quaternary sandstone occurs on Peron Peninsula.

The western side of the island is bounded by steep cliffs which range in height from 2 or 3 m to about 80 m near Herald Heights. The eastern side has a few comparatively low cliffs with extensive sandy and rocky beaches in between. Sand dunes lie behind the beaches in places.

The western side of the island is the higher, rising to 185 m at Herald Heights and to 155 m and 132 m further north. The middle parts consist mainly of well-vegetated stable sand dunes of reddish or whitish calcareous soil although in the area between Herald Heights and Tetrodon Loop there are a number of mobile white dunes, one of which touches the sea at Tetrodon Loop. Near the cliffs the soil is shallow and the limestone frequently crops out. A number of low-lying areas contain clay pans.

Climatological data are given in Table 1. It can be seen that most rain falls during the winter but that occasional summer cyclones or thunderstorms also bring rain. The rainfall on Dirk Hartog is higher than that on the adjacent mainland; only Carrarang and Tamala Stations to the south approach the figure for Dirk Hartog. This is possibly an orographic effect since Herald Heights and the other hills along the west side of Dirk Hartog Island are the highest land for some distance.

There is no standing fresh water on the island except in clay pans for a short time following heavy rain. Water has been provided for the sheep from wells. At Herald Heights there is a seepage in a small cave just below the clifftop. Stalactites and associated features have formed, indicating that the water supply, though small, must be fairly constant. It was dripping freely at the time of our visit in 1972.

Vegetation and flora

Shark Bay is the site of the first authenticated botanical collections by Europeans in Australia. William Dampier, on his second visit there between 6 and 12 August 1699, collected at least 18 species which are now in the Sherardian Herbarium at Oxford University (George 1971). Although he landed on Dirk Hartog Island, we do not know which of his plants were collected there. Dampier's name is commemorated in the genus *Dampiera* and the species *Beaufortia dampieri*. Several other names commemorating him have unfortunately been reduced to synonymy, e.g. *Clianthus dampieri* (now *C. formosus*) and *Eurybia dampieri* (*Olearia axillaris*).

Later visitors who collected around Shark Bay included Leschenault, Riedle, Péron and Guichenot with Baudin in 1801 and 1803 (Baudin 1974), Gaudichaud, Quoy and Gaimard with Freycinet in 1818 (Gaudichaud 1826), Cunningham with King in 1822 (King 1827), Grey in 1839 (Grey 1841), Milne with Denham in 1858 and Mueller in 1877 (Mueller 1883). Not all landed on Dirk Hartog Island. Since

Table 1

Climatic data for Dirk Hartog Island and nearby locations, from information supplied by the Bureau of Meteorology.

Rainfall (in mm)

Station	Mean	Median	Range
Dirk Hartog Homestead (1893-1948)			
January	6	0	0–89
February	12	4	0–135
March	13	2	0–130
April	16	7	0–74
May	56	47	0–299
June	88	88	7–222
July	62	50	17–202
August	35	29	4–122
September	14	8	0–61
October	7	5	0–40
November	2	0	0–11
December	2	0	0–34
Annual	313	290	120–681
Other Stations.			
Carrarang (1894–1973)	280	268	71–532
Tamala (1900–1975)	300	285	122–490
Denham (1893–1975)	236	223	78–522
Hamelin Pool (1885–1975)	213	194	45–409
Carbla (1913–1975)	216	190	63–446
Yaringa (1923–1975)	210	185	56–438
Wooramel (1898–1975)	201	184	60–472
Edaggee (1915–1975)	192	175	61–447
Carnarvon (1883–1950)	229	205	68–619

Evaporation (in mm)

Station	Annual average
Denham	2 032
Hamelin Pool	2 108
Carnarvon	2 465

Temperature (in °C).

	Carnarvon (29 years)		Hamelin Pool (17 years)	
	Max.	Min.	Max.	Min.
January	30·8	22·6	37·2	21·0
February	32·0	23·1	37·1	21·8
March	30·1	21·9	35·0	20·1
April	28·1	18·7	30·0	16·9
May	25·9	14·9	25·5	13·4
June	23·1	13·0	21·8	11·4
July	21·9	11·0	20·9	9·5
August	22·4	11·3	22·3	9·5
September	23·8	13·8	25·5	11·2
October	25·6	16·4	29·0	13·6
November	27·0	18·7	32·2	16·0
December	28·9	20·8	34·9	18·8
Annual	26·7	17·2	29·3	15·3

many of their specimens were described as new species, the area contains a number of type localities. Some of their names also are commemorated in genera and species such as *Lechenaultia, Guichenotia, Eucalyptus baudiniana Angianthus cunninghamii, Angianthus milnei* and *Rhagodia gaudichaudiana.*

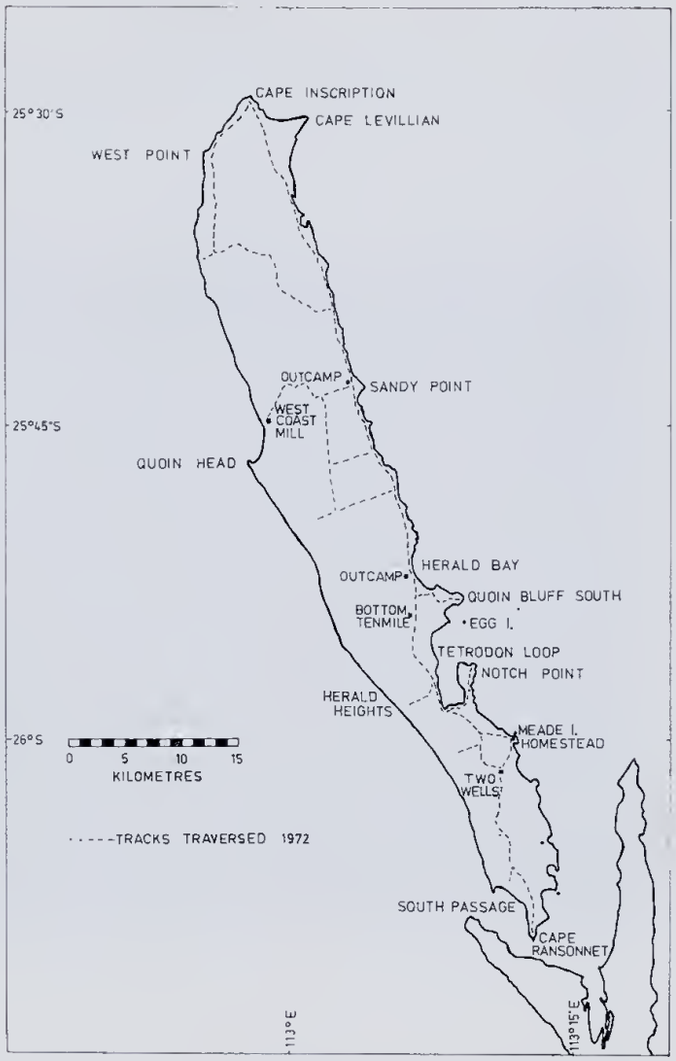

Figure 2.—Map of Dirk Hartog Island.

Mueller (1883) recorded 60 species based on early collections from Dirk Hartog Island, though many of the names he used are not in current use. They have been included under their current names in the flora list below excepting several species whose determination is doubtful and which are mentioned separately.

Although intermittent collecting continued on the mainland, after 1858 few plants were collected from the island until 1967 when a group of students from Wesley College, South Perth, visited it. In 1973, B. A. and A. G. Wells recorded 13 species, and in 1974 J. S. Beard made a small collection.

Our expedition of 1972 had the advantage of an excellent season, about 500 mm of rain having fallen between 1 January and 31 August 1972. Over 250 species were collected in flower or fruit. With flowering at its peak, many areas were extremely colourful, prominent species being *Acacia ligulata, Brachycome latisquamea, B. iberidifolia, Dampiera incana, Helipterum* spp., *Swainsona* spp. and *Thryptomene baeckeacea.* Some plants were not in flower, and collections at other seasons would probably

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Figure 3.—Tall open-heath dominated by *Acacia ligulata*, 0.8 km W of homestead.

increase the list of indigenous flora to about 300 species. Several indeed have been added by recent visits of officers of the Wildlife Research Centre.

Vegetation

The vegetation has been mapped and described by Beard (1976), who recognised four communities on the island, designated by his own terminology. This paper describes five communities based on the terminology of Specht *et al.* (1974). They are correlated with Beard's classification as used in his text.

1. *Tall open-heath.*—(Figure 3). (Beard: shrub steppe, a_{22} Si. x ZHc). This is by far the most extensive community, occupying the deep or shallow sand away from the coast and almost throughout the length of the island. It is usually dominated by *Acacia ligulata*, but several small areas are dominated by *Eucalyptus* of which there are 4 species. Other common tall shrubs are *Acacia coriacea, Pittosporum phylliraeoides, Diplolaena grandiflora, Heterodendrum oleifolium* and *Alyogyne cuneiformis*. Lower shrubs, up to 1 m tall, include *Atriplex bunburyana, Thryptomene baeckeacea, Beaufortia dampieri, Pimela microcephala, Ptilotus obovatus* and *Cassia chatelainiana*. The spinifex *Plectrachne* sp. is common, and the introduced Buffel Grass (*Cenchrus ciliaris*) has spread widely. The perennial scrambler *Brachycome latisquamea* is common.

In a few areas the vegetation is up to 3 m tall and should be termed tall shrubland, while in others it is sparse and becomes low shrubland or low open-shrubland.

2. *Low closed/open-heath with hummock grasses.*—(Figures 4, 5). (included with shrub steppe by Beard.) North of Sandy Point are areas of low heath, vaying from open to closed, with an admixture of spinifex (*Plectrachne* sp. and *Triodia plurinervata*). The myrtles *Thryptomene baeckeacea* and *Melaleuca cardiophylla* are common, and *Acacia ligulata* is still frequent. South Western elements predominate in the other shrubs which include *Calytrix strigosa, Cryptandra nudiflora, Pityrodia atriplicina, Acacia? leptospermoides, Geleznowia verrucosa, Guichenotia ledifolia, Daviesia* aff. *colletioides* and *Kcraudrenia hermanniifolia*. Two sedges were recorded—*Lepidobolus preissianus* and *Gahnia? lanigera*. Ephemeral herbs include *Brachycome iberidifolia, Swainsona* sp. and *Senecio lautus*. and the perennial *Brachycomc latisquamea* is frecuent. Occasionally the spinifexes are dominant almost as a hummock grassland.

Figure 4.—Low open-heath with hummock grassland, dominated by *Acacia ligulata* and *Triodia plurinervata*, N of Sandy Point Outcamp.

Formations similar to this or intermediate between it and the tall open-heath occur in other parts of the island, some apparently being the "full heath-spinifex community" described by Beard under mixed heath and spinifex.

3. *Low very-open-heath.*—(Figure 6). (Beard: mixed heath and spinifex, x ZHc. This term is not used by Specht but is used here for low heath (under 1 m tall) with cover less than 30%). The community occurs in shallow sand over limestone above rocky shores such as Quoin Bluff South and along the south-western coast. The shrubs include *Thrytomene baeckeacea, Scaevola crassifolia, Solanum orbiculatum, Frankenia pauciflora, Dampiera incana, Commersonia gaudichaudii* and *Atriplex* sp. *Plectrachne* sp. is present, and ephemeral herbs include *Lotus cruentus, Brachycome iberidifolia* and *Calocephalus francisii.*

A variant of low very-open-heath occurs on sandy flats near the shore at Sandy Point and farther north (Beard: dwarf scrub XZi). The ubiquitous *Thryptomene baeckeacea* is the common shrub, with some *Myoporum* sp. Perennial herbs include *Carpobrotus rossii, Conostylis stylidioides, Dicrastylis* sp. and *Spinifex longifolius.*

4. *Hummock grassland.*—(Beard: part of mixed heath and spinifex, x ZHc). Small areas tending towards hummock grassland among the low heath have already been mentioned, but quite extensive areas occur over the hills of Herald Heights. *Triodia plurinervata* is usually dominant, with some *Plectrachne* sp. Shrubs are low and sparse, and include *Pimelea gilgiana, Olearia axillaris* and *Thryptomene baeckeacea.*

5. *Low open-shrubland.*—(Figure 7). (Beard: samphire community, K_3 Ci). A number of saline flats occur on the island such as those to the south and west of the homestead on which the old and the new airstrips lie. Samphires dominate them, especially species of *Arthrocnemum* and *Salicornia.* The halophytes *Limonium, Atriplex* and *Samolus* are common, and herbs occur such as *Senecio glossanthus, Angianthus microcephalus* and *Parietaria debilis.*

The only stand of mangroves on the island is a small population of *Avicennia marina* by a soak on a saline flat at Tetrodon Loop.

Heavily grazed areas around mills and small holding pens have been mostly stripped of indigenous vegetation. Introduced plants have taken over, though most are ephemeral and these areas would be almost bare except after rain. The species include *Lolium loliaceum, Hordeum leporinum, Koeleria phleoides, Melilotus indicus, Medicago polymorpha, Erodium cicutarium* and *Spergularia rubra.*

Figure 5.—Low open-heath, dominated by *Thryptomene baeckeacea* and *Plectrachne* sp., 5 km N of Cape Ransonnet.

There are extensive blown out sandy areas quite without vegetation, for example near Tetrodon Loop and Mystery Beach. Along the west coast, rocky shores even atop cliffs are kept bare of vegetation by salt spray, sometimes up to 100 m from the sea.

Flora

The known indigenous flora of Dirk Hartog Island is listed in Table 2 and the naturalised flora in Table 3. Both lists are alphabetical. Table 2 cites the species, family, habit and habitat. The distribution on the mainland in the South West (SW) and Eremean (E) Botanical Provinces is shown in the first two columns, while the third (SB) denotes species restricted to the Shark Bay area. Species are included in the South West Province if their only other occurrence outside it (other than Dirk Hartog Island) is Bernier and Dorre Islands.

Representation of the larger families of the indigenous flora is shown in the following list.

Asteraceae	37	Mimosaceae	8
Chenopodiaceae	20	Myoporaceae	7
Poaceae	18	Amaranthaceae	6
Myrtaceae	13	Brassicaceae	6
Papilionaceae	13	Euphorbiaceae	6
Goodeniaceae	9	Sterculiaceae	6
Liliaceae	9	Zygophyllaceae	6
Malvaceae	8	Solanaceae	5

There are 2 families with 4 species, 8 with 3 species, 9 with 2 species and 32 with 1 species. The total number of indigenous families is 67.

The largest genera are *Acacia* (8 species), *Angianthus* (7 species), *Arthrocnemum* and *Ptilotus* (both with 6 species), *Rhagodia* (5 species), *Eucalyptus, Helipterum, Melaleuca, Scaevola, Swainsona* and *Zygophyllum* (all with 4 species). The number of genera is 167.

Several species recorded by Mueller should be checked before they can be definitely listed for the island.

They are:

Acacia spathulata F. Muell.—probably *A. leptospermoides* Benth.

Casuarina humilis Otto et Dietr.—probably *C. helmsii* Ewart & Gordon.

Convolvulus sepium L.—? incorrect locality.

Dicrastylis fulva Drumm. et Harv.—probably undescribed.

Frankenia laevis L.—probably *F. pauciflora* DC.

Ptilotus striatus F. Muell.—probably *P. divaricatus* (Gaud.) F. Muell.

Figure 6.—Limestone cliff at Quoin Bluff South with low very open-heath.

Verticordia pennigera Endl.—? incorrect locality.

Melaleuca holosericea Schau.—? incorrect locality.

Excluding these, the known indigenous flora totals 259 species.

The flora of the island is of great interest phytogeographically. Morphologically the island populations, excluding of course several species known only on it, lie within the range of variation shown by those on the mainland. It is the size of the flora and more especially the geographical range of its components which demand attention. With 259 known indigenous species and an estimated total of about 300, the flora is easily the largest of any island off the lower western and southern Western Australian coasts. While this is expected on the much larger island that Dirk Hartog is, it is apparently also a much richer flora than that of the nearby peninsulas—Edel Land and Peron Peninsula. This is probably directly due to the higher rainfall on the island.

The flora is quite evenly divided between South Western and Eremean species, among which the following groups deserve mention.

1. Those apparently endemic to the island: *Gnephosis tenuissima, Stipa crinita, Trachymene elachocarpa, Olearia* sp. inedit., *Arthrocnemum* sp. inedit., *Chrysopogon* sp. inedit., *Scirpus* sp.
2. Those restricted to the Shark Bay area, i.e. the adjacent mainland, some extending along the coast north of Carnarvon. They are shown in the last column of Table 2 and total 18.
3. Those South Western species (54 in all) at their northern limit on the island, marked by an asterisk in Table 2. Some of these also represent the northern limit of the respective families in the South West Botanical Province. They are Casuarinaceae, Centrolepidaceae, Haemodoraceae, Orchidaceae and Restionaceae.
4. Those which are well isolated from their nearest known population on the mainland. These are *Helipterum oppositifolium* (nearest population Bullfinch); *Casuarina helmsii* (Arrino); *Melaleuca lanceolata* (Geraldton); *Neosciadium glochidiatum* (Drummond collection: ? near Perth); *Limosella australis* (Harvey).

Figure 7.—Low open-shrubland dominated by *Arthrocnemum* spp., on (new) airstrip flat.

The indigenous flora of Dirk Hartog Island is over twice that of Bernier and Dorre Islands (Royce in Ride *et al.* 1962), which lie just to the north and, though much smaller, are geologically similar but receive a lower rainfall. Recent collecting by K. F. Kenneally during post-fire regeneration studies on Dorre Island has added 16 species to that island's flora (Kenneally pers. comm.). The total for Dorre of 109 species and for Bernier of 96 species compares with 259 for Dirk Hartog. Discounting the marine *Halophila ovalis*, twenty-six species on Bernier and Dorre have not so far been collected on Dirk Hartog. Almost all are Eremean species, reflecting the lower rainfall on those islands. Of over 150 species on Dirk Hartog not recorded for Bernier and Dorre, the most interesting is the unnamed *Plectrachne*, common on Dirk Hartog but known otherwise only from Edel Land.

At the time of our visit the vegetation was generally in good condition, especially in the northern half of the island where there were no sheep. There was no sign of recent fire, and we understand that for many years fire has not been used in pastoral management on the island. There are few fire-adapted species on the island. Provided that populations of grazing and browsing animals do not build up enough to cause overgrazing, the flora should maintain itself without requiring a great deal of management.

Dirk Hartog Island: South West or Eremean Province?

Beard (1976) determined a precise boundary for the South West Botanical Province in this region (his Fig. 2 p. 13 and Fig. 3 p. 27), leaving most of Edel Land, Peron Peninsula and the islands in the Eremean Province. He concluded that the Dirk Hartog communities "should be placed within the Eremean Province while recognising their intermediate character." In reaching this conclusion he gave "due weight" to "floristics, physiognomy and habitat". However, his visit to the island was made in a dry season and he stated that the "whole impression is one of desolation and aridity". This contrasts with the excellent condition and flowering of the flora during our visit. Since a good proportion (62%) of the species are shrubs or perennial herbs there is always a cover, albeit often open, of vegetation.

Floristically the island is almost equally divided between the provinces but with a leaning to the South West. Of the named species in Table 2, 77 are South Western, 61 are Eremean and 102 are common to both. However a number of species listed as Eremean have taxonomic affinities with the South Western flora, e.g. *Beaufortia dampieri, Pileanthus limacis, Beyeria cyanescens, Dampiera incana, Lechenaultia sub-*

Table 2

The known indigenous flora of Dirk Hartog Island, arranged alphabetically with the distribution on the mainland shown in the three columns: SW—South West Botanical Province; E—Eremean Province; SB—Shark Bay area only. Species at their northern limit on Dirk Hartog Island are marked by an asterisk in the SW or E column.

	SW	E	SB
Abutilon geranioides (DC.) Benth. Malvaceae .... Scrambling shrub 1·3 m, fls pale yellow. In sand over limestone, among low open-heath.		X	X
Abutilon oxycarpum F. Muell. Malvaceae .... Slender shrub to 50 cm; fls yellow inside with brown centres, brownish outside. In sand, in tall open-heath.		X	
Acacia bivenosa DC. Mimosaceae		X	
Acacia coriacea DC. Mimosaceae .... Spreading shrub to 2·5 m. On rocky, limestone flat near west coast, in low open-shrubland, and in sand in open-heath.		X	
Acacia idiomorpha A.Cunn. ex Benth. Mimosaceae Low, straggling shrub 30 cm. In sand, in low open-heath.	X*		
Acacia leptospermoides* Benth. Mimosaceae .... Sprawling shrub 40 cm. In sand, in tall open-heath.	X*		
Acacia leptospermoides Benth. Mimosaceae .... Shrub to 3 m; bark smooth, grey. In sand, in tall open-heath.	X*		
Acacia ligulata A.Cunn. ex Benth. Mimosaceae .... Spreading shrub to 2·5 m; bark smooth, grey, becoming fissured when old. Common throughout island, especially in sand, in tall open-heath and low open-heath.	X	X	
Acacia tetragonophylla F.Muell. Mimosaceae .... Spreading shrub to 1·7 m. In sand, in tall open-heath.	X	X	
Acacia sp. Mimosaceae .... Shrub 1·5 m, in leaf only. In sand, in tall open-heath. Only 1 population seen.		X	X
Acanthocarpus preissii Lehm. Liliaceae .... Straggling perennial herb. In sand, in tall open-heath.	X		
Acanthocarpus sp. Liliaceae ... . Tough perennial herb to 60 cm, forming clumps. In sand, in tall open-heath. A larger, more robust plant than *A. preissii*. Also occurs on the coastal plain west of the Cape Range.		X	X
Alyogyne cuneiformis (DC.) Lewton. Malvaceae .... Shrub to 3 m; fl white with red centre (only 1 fl. seen). In sand, in tall open-heath.	X	X	X
Alyogyne pinonianus (Gaud.) Fryxell. Malvaceae Shrub 1·3 m; fl mauve (only 1 fl seen). In sand, in tall open-heath.	X	X	
Amphibolis antarctica (Labill.) Sond. et Aschers Potamogetonaceae Collected by Gaudichaud.			
Amyema linophyllum (Fenzl) Tiegh. Loranthaceae Collected by Milne.	X		
Amyema preissii (Miq.) Tiegh. Loranthaceae .... Mistletoe on *Acacia ligulata*. In tall open-heath.	X	X	
Angianthus cunninghamii (DC.) Benth. Asteraceae	X	X	
Angianthus microcephalus (F.Muell.) Benth. Asteraceae .... Ephemeral herb. On saline flat, in low open-shrubland.	X*	X	
Angianthus milnei Benth. Asteraceae .... Collected by Milne.		X	
Angianthus strictus (Steetz) Benth. Asteraceae .... Ephemeral herb; fls yellow. In loam, in open grazed area near mill.	X	X	
Angianthus tomentosus Wendl. Asteraceae .... Ephemeral herb.	X	X	
Angianthus sp. ASG 11362. Asteraceae .... Ephemeral herb; fls immature. In loam over limestone, in open grazed area.			
Angianthus sp. ASG 11471. Asteraceae .... Ephemeral herb aromatic; fls yellow. In limestone, in low very open-heath.			
Anguillaria monantha Endl. Liliaceae .... Bulbous herb, in fruit. In sand, in tall open-heath.	X*		
Anthotroche walcottii F.Muell. Solanaceae .... Collected by Milne.	X*		
Aphanopetalum clematidemn (Drumm. et Harv.) C. A. Gardn. Cunoniaceae .... Climber; fls cream-green. In sand, in low open-heath.	X*		
Aristida contorta F.Muell. Poaceae .... Collected by Gaudichaud.		X	X
Arthrocnemum bidens Nees. Chenopodiaceae .... Sprawling, succulent shrub, ± dull green. On saline flat, in low open-shrubland.	X	X	
Arthrocnemum halocnemoides Moq. Chenopodiaceae Shrub to 70 cm, ± yellow-green. On saline flat, in low open-shrubland.	X	X	
Arthrocnemum pruinosum Paulsen. Chenopodiaceae Succulent shrub. On saline flat, in low open-shrubland.		X	
Arthrocnemum sp. ASG 11609. Chenopodiaceae Sprawling, succulent perennial herb to 10 cm tall. On saline flat, in low open-shrubland.		X	
Arthrocnemum sp. ASG 11430. Chenopodiaceae Succulent shrub, red and green. On saline flat, in low open-shrubland.		X	
Arthrocnemum sp. ASG 11454a. Chenopodiaceae Succulent shrub, ± bright green. On saline flat, in low open-shrubland.		X	X
Atriplex bunburyana F.Muell. Chenopodiaceae .... Shrub to 1 m. In sand, on coastal dune by beach and in tall open-heath.	X	X	
Atriplex cinerea Poir. Chenopodiaceae .... Shrub 1 m. dioecious. In saline mud near soak, with *Avicennia marina*.		X	
Atriplex vesicaria Benth. Chenopodiaceae		X	
Avicennia marina (Forsk.) Vierh. Avicenniaceae .... Mangrove; shrub 3 m with pneumatophores. In saline mud by soak near coast. Only 1 small population seen.	X	X	
Baeckea pentagonantha F. Muell. Myrtaceae .... Collected by Milne.	X*		
Bassia uniflora (R.Br.) F.Muell. Chenopodiaceae Sprawling shrub 30 cm tall. In sand over limestone near cost, in tall open-heath.	X	X	
Beaufortia dampieri A. Cunn. ex Hook. Myrtaceae Spreading shrub to 1·5 m tall; fls pale pink to white. On sand dunes, in tall open-heath.	X		

Table 2—*continued*

	SW	E	SB
Beyeria cyanescens (Muell. Arg.) Benth. Euphorbiaceae .... Much-branched shrub 35 cm, dioecious. In sand, in tall open-heath.	X	X	
Bidens bipinnata L. Asteraceae .... Ephemeral herb; fls yellow. On rocky, limestone flat near west coast, in low open-shrubland.		X	
Boerhavia chinensis (L.) Aschers and Schweinf. Nyctaginaceae .... Sprawling perennial herb; fls deep pink. On rocky, limestone flat near west coast, in low open-shrubland.		X	
Bossiaea rufa R.Br. var. *foliosa* Benth. Papilionaceae Spreading shrub 30 cm; fls yellow and red. In sand. in tall open-heath.	X*		
Brachycome ciliaris (Labill.) Less. Asteraceae .... Ephemeral herb; rays pale mauve. In sand over limestone, in low open-shrubland.	X	X	
Brachycome iberidifolia Benth. Asteraceae .... Ephemeral herb; rays mauve. Common in many areas, in sand or on limestone. In open-heath, low-shrubland.	X	X	
Brachycome latisquamea F.Muell. Asteraceae .... Scrambling shrub to 1·5 m; rays mauve, rarely white. In sand, in tall open-heath and low shrubland; fairly common.		X	X
Brachysema macrocarpum Benth. Papilionaceae .... Perennial herb. In sand, in tall open-heath.		X	X
Cakile maritima L. Brassicaceae .... Perennial herb; fls pink. In sand above beach by homestead.	X	X	
Calandrinia polyandra Benth. Portulacaceae .... Ephemeral herb with succulent lvs; fls bright pink inside, centres often darker, pale yellow outside. In sand, in open-shrub, and in limestone near sea.	X	X	
Calandrinia sp. Portulacaceae .. . . Succulent ephemeral herb. reddish. In sand over limestone, in low open-shrubland.			
Calocephalus francisii (F.Muell.) Benth. Asteraceae Ephemeral herb; fls white or pale yellow. In sand, in low open-heath.	X	X	
Calogyne berardiana (Gaud.) F.Muell. Goodeniaceae Ephemeral herb; fls yellow. On sand dune, in low open-heath.	X	X	
Calotis multicaulis (Turcz.) Druce. Asteraceae .... Ephemeral herb: rays white. In loam over limestone, in open grazed area.		X	
Calytrix strigosa A. Cunn. Myrtaceae .... Sprawling shrub 25 cm; fls purple, stamens yellow. In sand, in low open-heath.	X*		
Capparis spinosa L.var. *nummularia* (DC.) F. M. Bailey. Capparidaceae .... Shrub ± 1 m. In limestone, in tall open-heath.	X	X	
Carpobrotus rossii (Haw.) Schwantes. Aizoaceae .... Prostrate perennial herb with succulent lvs; fls pale pink to white. In white sand, in low open-heath.	X	X	
Cassia chatelainiana Gaud. Caesalpiniaceae .... Shrub to 1 m; fls bright yellow. In sand. in tall open-heath.	X	X	
Cassytha nodiflora Meisn. Lauraceae .... Parasitic climber. In low open-shrubland near cosat.	X		
Cassytha pubescens R.Br. Lauraceae .... Parasitic climber. In tall open-heath.		X	X
Casuarina helmsii Ewart and Gordon. Casuarinaceae Sprawling shrub 40 cm tall x 2 m broad. Rare, in sand in low closed/open-heath. In East Sandy Paddock, only male seen; in Blowhole Paddock, male and female seen.	X	X	
Centrolepis humillima F.Muell. ex Benth. Centrolepidaceae .... On saline flat in low open-shrubland.	X*		
Cephalipterum drummondii A. Gray. Asteraceae .... Ephemeral herb; bracts yellow or white. In loam over limestone, in open grazed area.	X	X	
Chamaesyce myrtoides (Boiss.) Hassall. Euphorbiaceae Ephemeral herb.		X	
Chorizema ericifolium Meisn. Papilionaceae .... Shrub to 40 cm; fls yellow and red. In sand, in low open-heath/hummock grassland.	X	X	
Chrysopogon sp. ASG 11544. Poaceae .... Perennial grass with underground rhizomes. In sand near seashore.			
Clematis microphylla DC. Ranunculaceae .... Climber; fls white. In sand, in tall open-heath.	X		
Commersonia gaudichaudii J. Gay. Sterculiaceae .... Spreading shrub; fls white. In sand, in low very open-heath.	X*	X	
Conostylis stylidioides F.Muell. Haemodoraceae Caespitose perennial herb; fls yellow. In sand, in tall open-heath and in low very open-heath.	X*		
Corynotheca micrantha (Lindl.) Macbride. Liliaceae Sprawling perennial herb; fls pale pink to white. On coastal dune, in tall open-heath.	X		
Cotula cotuloides (Steetz) Druce. Asteraceae. .... Ephemeral herb. In sand, in open grazed area by mill.	X	X	
Crassula colorata (Nees) Ostenf. Crassulaceae .... Ephemeral herb. In sand, in tall open-heath.	X	X	
Cryptandra nudiflora F.Muell. Rhamnaceae .... Low shrub. In sand, in low open-heath.	X*		
Cymbopogon ambiguus A. Camus. Poaceae .... Perennial grass. On sand dune, in low open-heath.	X	X	
Cyperus bulbosus Vahl. Cyperaceae .... Rhizomatous sedge; fls brown.		X	
Dampiera incana R.Br. Goodeniaceae .... Perennial herb to 50 cm; fls deep blue. In sand, in tall and low open-heath.		X	X
Danthonia racemosa R.Br. Poaceae .... Collected by Gaudichaud.	X*		
Daucus glochidiatus (Labill.) Fisch. Mey. and Ave-Lall. Apiaceae .... Ephemeral herb. In sand, in tall open-heath.	X	X	
Daviesia aff. *colletioides* Meisn. Papilionaceae .... Much-branched shrub 40 cm; fls yellow and red. In sand, in tall open-heath.	X		
Dianella revoluta R.Br. Liliaceae .... Caepitose perennial herb; fls blue. In sand, in tall open-heath.	X	X	

Table 2—*continued*

	SW	E	SB
Dichopogon strictus (R.Br.) Baker. Liliaceae .... Herb with tubers; fls mauve. In sand, in tall open-heath.	X*		
Dicrastylis sp. Chloanthaceae .... Perennial herb, in leaf only. In sand above beach by homestead, and at Sandy Point in low shrubland.		X	X
Diplolaena grandiflora Desf. Rutaceae . .... Shrub to 2 m; bracts red, fls orange to pale green. Common, especially in sand in tall open-heath.	X	X	
Diplolaena microcephala Desf. Rutaceae .... Shrub to 1·7 m; fls red-pink. In sand, in tall open-heath.	X*		
Dodonaea aptera Miq. Sapindaceae .... Shrub 70 cm. In sand, in tall open-heath.	X*		
Dodonaea inaequifolia Turcz. Sapindaceae .... Shrub to 1·3 m; fr red and green, ± viscid. In sand over limestone cliff top, in tall open-heath.	X*	X	
Dysphania plantaginella F.Muell. Chenopodiaceae Ephemeral herb; fls pale green. In sand over limestone, in low open-heath.		X	
Enchylaena tomentosa R.Br. Chenopodiaceae .... Shrub 70 cm; fr orange. In sand, in tall open-heath.	X	X	
Enneapogon caerulescens (Gaud.) N. T. Burbidge. Poaceae .... Small, caespitose. perennial grass; fls lead-green. In sand over limestone on cliff top, in low open-heath.		X	
Eragrostis? *brownii* (Kunth) Nees. Poaceae .... Small ephemeral grass. In sand, in tall open-heath.	X		
Eragrostis dielsii Pilger. Poaceae .... Prostrate ephemeral grass; fls green-purplish. In loam over limestone, in open grazed area by mill.	X	X	
Eremophila clarkei F.Muell. Myoporaceae .... Spreading shrub 1 m tall; fls pale to deep pink. In sand, in tall open-heath.	X	X	
Eremophila glabra (R.Br.) Ostenf. Myoporaceae ... Shrub 25-130 cm; fls red (3 variants collected). In sand, in tall and low open-heath.	X	X	
Eremophila oldfieldii F.Muell. Myoporaceae .... Shrub to 1·5 m; fls dull red. In sand over limestone on cliff top, in tall open-heath.	X	X	
Eriachne mucronata R.Br. Poaceae .... Caespitose perennial grass. In sand, in tall open-heath.		X	
Eriochilus dilatatus Lindl. Orchidaceae .... Orchid with tuber; in old fruit. On sandy hill, in low open-heath.	X*		
Erodium angustilobum Carolin. Geraniacaeae .... Ephemeral herb.		X	
Erodium cygnorum Nees subsp. *cygnorum*. Geraniaceae .... Ephemeral herb.	X	X	
Eucalyptus baudiniana Carr & Carr. Myrtaceae .... Sprawling mallee 1·5 m. In sand, in tall open-heath.	X		
Eucalyptus dongarraensis Maiden & Blakely. Myrtaceae .. .. Mallee 1-2·5 m; bark rough at base, exfoliating in broad, ± smooth strips above. In sand or sand over limestone in tall open-heath.	X	X	
Eucalyptus foecunda Schau. Myrtaceae . Dense, sprawling mallee 1-2 m tall; lower bark rough, upper smooth, fls white. In sand, in tall open-heath.	X		
Eucalyptus tamala Carr & Carr. Myrtaceae .. Sprawling mallee 1·5 m tall; bark rough at base, smooth above. In sand, in tall open-heath.	X		
Eulalia fulva (R.Br.) O. Kuntze. Poaceae .... Perennial grass; fls brown. In limestone, in low very open-heath.		X	
Euphorbia eremophila A. Cunn, ex Hook. Euphorbiaceae . ... Ephemeral herb with latex. In sand, in low open-heath/hummock grassland	X	X	
Euphorbia sharkoensis Baill. Euphorbiaceae .... Ephemeral herb.	X		
Exocarpos aphyllus R.Br. Santalaceae .... Much-branched shrub 2 m; fls greenish-yellow. In sand, in tall open-heath.	X	X	
Frankenia cinerea DC. Frankeniaceae .... Small shrub to 10 cm tall; fls white. On saline flat. in low open-shrubland.		X	
Frankenia pauciflora DC. Frankeniaceae	X	X	
Gahnia? *lanigera* (R.Br.) Benth. Cyperaceae .... Caespitose perennial sedge. In sand over limestone, in low open-heath.	X*		
Geleznowia verrucosa Turcz. Rutaceae . .... Small shrub to 35 cm; fls yellow. In sand, in low closed-heath	X*		
Glycine tabacina (Labill.) Benth. Papilionaceae .... Slender climber; fls deep pink In sand over limestone, in low open-heath	X	X	
Gnaphalium luteoalbum L. Asteraceae .... Ephemeral herb. In sand by homestead.	X	X	
Gnaphalodes condensatum A. Gray. Asteraceae .... Ephemeral herb; fls cream-green. In sand over limestone, in low open-heath.	X	X	
Gnephosis macrocephala Turcz. Asteraceae .... Ephemeral herb; fls yellow. In sand, in open-heath.	X		
Gnephosis skirrophora (Sond.) Benth. Asteraceae .... Collected by Milne.	X	X	
Gnephosis? *tenuissima* Cass. Asteraceae	X		
Goodenia sp. ASG 11508. Goodeniaceae .... Herb with underground stolons; fls yellow. In sand, in low open-heath.			
Grevillea stenophylla W. V. Fitzg. Proteaceae .... Sprawling shrub 40 cm; fls cream on reddish pedicels. In sand, in closed-heath.	X*		
Guichenotia ledifolia J. Gay. Sterculiaceae .... Spreading shrub to 80 cm; fls pale pink. In sand, in tall open-heath.	X*		
Gyrostemon ramulosus Desf. Gyrostemonaceae .... Tree 3 m, male; no female seen. In sand, as emergent in tall open-heath.	X	X	
Halgania littoralis Gaud. Boraginaceae .... Shrub 40 cm; fls deep blue. In sand, in low open-heath/hummock grassland.	X		
Haloragis gossei F. Muell. Haloragaceae .... Ephemeral herb.		X	

Table 2—*continued*

	SW	E	SB
Haloragis trigonocarpa F. Muell. Haloragaceae .... Ephemeral herb. In loam over limestone, in open grazed area.		X	
Hannafordia quadrivalvis F.Muell. Sterculiaceae .... Shrub 35 cm; fls pale yellow, brown outside. In sand, in tall open-heath.	X	X	
Helipterum condensatum F.Muell. Asteraceae .... Ephemeral herb; bracts white; fls yellow. On coastal dune, in tall open-heath.	X	X	
Helipterum humboldtianum (Gaud.) DC. Asteraceae Ephemeral herb; fls bright yellow. In sand, in tall open-heath.	X	X	
Helipterum oppositifolium S.Moore. Asteraceae .... Ephemeral herb; bracts cream-white and bronze. In sand over limestone, in low open-heath.		X*	
Helipterum polycephalum (A.Gray) Benth. Asteraceae .... Ephemeral herb; fls cream. In sand over limestone, in shelter of shrubs in tall open-heath.	X		
Heterodendrum oleifolium Desf. Sapindaceae .... Shrub to 3 m. In limestone, in tall open-heath.		X	
Hymenolobus procumbens (L.) Nutall. Brassicaceae Ephemeral herb. In soil pockets on limestone by sea, and on saline flat near airstrip.	X*		
Indigofera boviperda A.Morrison. Papilionaceae .... Sprawling perennial herb; fls deep pink. In sand, in low open-heath.		X	
Jasminum calcareum F.Muell. Oleaceae .... Small shrub or straggling climber; fls white, sweetly scented. In sand, in tall open-heath.		X	
Juncus bufonius L. Juncaceae .... In sand, in open grazed area by mill.	X		
Kennedia prostrata R.Br. Papilionaceae .... Collected by Gaudichaud	X*		
Keraudrenia hermanniifolia J.Gay. Sterculiaceae .... Shrub to 35 cm; fls purple with yellow stamens. In sand, in tall open-heath.	X		
Lasiopetalum angustifolium W.V.Fitzg. Sterculiaceae Spreading shrub to 40 cm tall; fls pale pink. In sand in tall open-heath.	X		
Lawrencia densiflora (Bak.f.) Melville. Malvaceae In sand, in tall open-heath.		X	
Lawrencia sp. Malvaceae			
Lechenaultia linarioides DC. Goodeniaceae .... Tangled perennial herb 1 m; fls yellow and red. In sand, in low open-heath.	X*		
Lechenaultia subcymosa Gardn. & George. Goodeniaceae .... Perennial herb; fls pale mauve. In sand over limestone, in low open-heath.		X	X
Lepidium linifolium (Desv.) Benth. Brassicaceae .... Straggling ephemeral herb to 1 m tall, fls white. In sand, in tall open-heath.	X	X	
Lepidium pseudo-ruderale Thell. Brassicaceae .... Slender ephemeral herb. In sand, in mustering yard.	X*		
Lepidium rotundum DC. Brassicaceae .... Ephemeral herb. In sand, in tall open-heath.	X	X	
Lepidobolus preissianus Nees. Restionaceae .... Caespitose sedge, dioecious. In sand, in low open-heath.	X*		
Leptomeria spinosa (Lehm.) DC. Santalaceae .... Collected by Cunningham.	X		
Limonium salicorniaceum (F.Muell.) Kuntze. Plumbaginaceae .... Perennial herb; fls white. On saline flat, forming closed herbland with *Samolus*, *Atriplex*, etc. around small soak.		X	
Limosella australis R.Br. Scrophulariaceae .... Ephemeral herb; fls white In loam over limestone, in open grazed area by mill.	X*		
Loania sp. Loganiaceae	X		
Lotus cruentus Court. Papilionaceae .... Ephemeral herb; fls maroon. In sand, in low open-heath near coast.		X	
Loxocarya flexuosa (R.Br.) Benth. Restionaceae .... Caespitose perennial sedge. In sand, in low open-heath.	X*		
Lysiana murrayi (F.Muell. et Tate) Tiegh. Loranthaceae .... Mistletoe on *Acacia ligulata*.		X	
Melaleuca cardiophylla F.Muell. Myrtaceae .... Shrub. In sand, in tall and low open-heath.	X	X	
Melaleuca aff. *heugelii* Endl. Myrtaceae .... Sprawling shrub 1 m tall x 4 m broad; fls pink. In sand or limestone, in low open-heath.	X*		
Melaleuca lanceolata Otto. Myrtaceae .... Spreading shrub or tree to 4 m; bark grey, stringy. In shell grit near saline flat.	X*		
Melaleuca? oldfieldii F.Muell. Myrtaceae	X*		
Millotia myosotidifolia (Benth.) Steetz. Asteraceae Ephemeral herb; fls white. On sand dunes in open-heath near coast.	X	X	
Mirbelia ramulosa (Benth.) C. A. Gardn. Papilionaceae .... Sprawling shrub, fls yellow and red. In sand, in low open-heath/hummock grassland.	X	X	
Myoporum acuminatum R.Br. Myoporaceae .... Shrub 1 m; fls white. On coastal dune, in tall open-heath.	X	X	
Myoporum adscendens R.Br. Myoporaceae	X		
Myoporum deserti A.Cunn. ex Benth. Myoporaceae Shrub 50 cm. In sand, in open-heath.	X	X	
Myoporum tetrandrum (Labill.) Domin. Myoporaceae Collected by Cunningham and Milne.	X*		
Neosciadium glochidiatum (Benth.) Domin. Apiaceae Ephemeral herb; fls cream. On saline flat, in low open-shrubland.	X*		
Nicotiana occidentalis Wheeler. Solanaceae .... Ephemeral herb; fls pale cream. In sand. in tall open-heath.	X	X	
Nitraria schoberi L. Zygophyllaceae .... Much-branched shrub to 2 m; fls pale greenish-cream. On sand dune by coast, in tall open-heath.	X	X	
Olearia axillaris (DC.) Benth. var. *obovata* Benth. Asteraceae	X		
Olearia pimelioides (DC.) Benth. Asteraceae		X*	
Olearia sp. ASG 11568. Asteraceae .... Straggling shrub, rays white. In limestone, in tall open-heath.			

Table 2—*continued*

	SW	E	SB
Opercularia spermacocea Labill. Rubiaceae .... Perennial herb to 35 cm. In sand, in low open-heath.	X*		
Ophioglossum lusitanicum L. subsp. *coriaceum* (A. Cunn.) Clausen. Ophioglossaceae .... In sandy pockets on limestone, in low open-heath.	X	X	
Oxalis corniculata L. Oxalidaceae .... Fls yellow. In shelter of shrubs of sandy depression, in tall open-heath.	X	X	
Paractaenum novae-hollandiae Beauv. Poaceae .... Ephemeral grass; fls purplish. In sand, in mustering yard.		X	
Parietaria debilis Forst.f. Urticaceae .... Ephemeral herb; stems red, fls green. On saline flat, in low open-shrubland, and in limestone by sea.	X	X	
Paspalidium gracile (R.Br.) Hughes. Poaceae .... Perennial grass; fls green. On rocky limestone near coast, in low open-shrubland.	X	X	
Pentatropis linearis Dcne. Asclepiadaceae .... Climber; fls pale brown-green. In sand, in tall open-heath.		X	
Phyllanthus? crassifolius Muell. Arg. Euphorbiaceae Small shrub. In limestone, in low shrubland.	X		
Pileanthus limacis Labill. Myrtaceae .... Sprawling shrub to 70 cm tall x 3 m broad, fls pale pink. In limestone soil, on cliffs by sea.		X	X
Pimelea gilgiana E.Pritzel. Thymelaeaceae .... Shrub to 35 cm, dioecious; fls white, mostly over. In sand, in hummock grassland and low shrubland.	X*		
Pimelea microcephala R.Br. Thymelaeaceae .... Shrub to 1·5 m, dioecious; male fls cream; fr orange or red. In sand, in tall and low open-heath and low shrubland.	X	X	
Pittosporum phylliraeoides DC. Pittosporaceae .... Tree to 3 m; fls cream. In sand, as emergent in tall open-heath, and at base of cliff near sea.	X	X	
Pityrodia atriplicina (F.Muell.) F.Muell. ex Benth. Chloanthaceae .... Shrub 1 m; fls pink. In sand, in low closed-heath/hummock grassland.	X*		
Pityrodia cuneata (Gaud.) Benth. Dicrastylidaceae Much-branched shrub to 1 m; fls pale pink, spotted. In sand, in low open-heath.	X		
Plantago varia R.Br. Plantaginaceae .... In loam over limestone, in open grazed area.	X	X	
Plectrachne sp. Poaceae .... Spinifex; fls straw-pale purple. Common, especially in sand, in tall or low open-heath and hummock grassland.	X*	X	
Podolepis canescens A. Cunn. ex DC. Asteraceae Ephemeral herb; fls yellow.	X	X	
Podolepis gardneri G. L. Davis. Asteraceae		X	
Podotheca angustifolia (Labill.) Less. Asteraceae .... Ephemeral herb; fls pale yellow. In sand, in tall open-heath.	X*		
Podotheca gnaphalioides Grah. Asteraceae .... Ephemeral herb. In sand, in tall open-heath.	X*	X	
Porana sericea (Gaud.) F.Muell. Convolvulaceae Climber; fls blue-purple. In sand, in tall open-heath.	X	X	
Poranthera microphylla Brongn. Euphorbiaceae .... Ephemeral herb. In sand, in tall open-heath.	X	X	
Ptilotus alexandri Benl. Amaranthaceae .... Ephemeral herb. In sand, in tall open-heath.		X	X
Ptilotus divaricatus (Gaud.) F.Muell. Amaranthaceae Straggling perennial herb; fls pink. In sand, in low open-heath.	X	X	
Ptilotus exaltatus (Nees) Benth. Amaranthaceae .... Ephemeral herb; fls pink. In sand, in tall open-heath.	X	X	
Ptilotus gaudichaudii (Steud.) J. M. Black var. *parviflorus* (Benth.) Benl. Amaranthaceae .... Ephemeral herb; fls yellow. In sand, in tall open-heath.	X	X	
Ptilotus obovatus (Gaud.) F.Muell. Amaranthaceae Shrub to 70 cm; fls pink.	X	X	
Ptilotus villosiflorus F.Muell. Amaranthaceae .... Ephemeral herb; fls cream-green and pale pink. On sand dune by coast. in open-heath.	X	X	
Rhagodia crassifolia R.Br. var. *latifolia* Benth. Chenopodiaceae		X	X
Rhagodia gaudichaudiana Moq. Chenopodiaceae Collected by Gaudichaud.	X		
Rhagodia preissii Moq. Chenopodiaceae .... Shrub to 1·3 m; fruit succulent red.	X	X	
Rhagodia sp. ASG 11503. Chenopodiaceae Sprawling shrub. In sand, in tall open-heath.			
Rhagodia sp. ASG 11580. Chenopodiaceae .... Shrub 40 cm. In sand over limestone, in low open-heath.			
Rulingia cygnorum (Steud.) C. A. Gardn. Sterculiaceae .... Shrub to 40 cm; fls cream. In sand over limestone, in low open-heath.	X*		
Ruppia maritima L. Ruppiaceae .... Aquatic herb. In pool on saline flat.	X*	X	
Salicornia blackiana Ulbrich. Chenopodiaceae .... Shrub. red and green. On saline flat, in low open-shrubland.	X		
Salsola kali L. subsp. *ruthenica* (Iljen) Soo. Chenopodiaceae .... On sand dunes by coast.	X	X	
Samolus repens (Forst.) Pers. Primulaceae .... In limestone, by coast.	X	X	
Santalum spicatum (R.Br.) D.C. Santalaceae .... Shrub. In sand. in tall open-heath.	X	X	
Sarcostemma australe R.Br. Asclepiadaceae .... Shrub to 1·5 m with latex; fls cream. In sand, in tall open-heath.	X	X	
Scaevola crassifolia Labill. Goodeniaceae .... Shrub to 1 m; fls white or pale blue. In sand, in low open-heath.	X	X	
Scaevola holosericea De Vr. Goodeniaceae .... Perennial herb to 40 cm; fls pale blue. In sand, in tall open-heath.	X	X	

Table 2—*continued*

	SW	E	SB
Scaevola spinescens R.Br. Goodeniaceae .... Divaricately-branched shrub to 70 cm; fls white. In sand, in tall open-heath.	X	X	
Scaevola tomentosa Gaud. Goodeniaceae .... Much-branched shrub to 1·5 m; fls gold, turning orange, anthers brown. In sand, in tall open-heath.	X	X	
Scirpus cernuus Vahl. Cyperaceae .... In limestone, in open grazed area.	X*		
Scirpus sp. ASG 11610. Cyperaceae .... Small ephemeral sedge. On saline flat, in low open-shrubland.			
Senecio glossanthus (Sond.) Belcher. Asteraceae .... Ephemeral herb. On saline flat, in low open-shrubland.	X	X	
Senecio lautus Willd. Asteraceae .... Perennial herb; fls yellow. In sand or limestone, in low open-heath.	X	X	
Sida calyxhymenia J. Gay. Malvaceae .... Shrub 70 cm; fls pale yellow. In sand, in tall open-heath.	X	X	
Sida corrugata Lindl. Malvaceae		X	
Solanum lasiophyllum Dun. Solanaceae	X	X	
Solanum aff. *oldfieldii* F.Muell. Solanaceae .... Small shrub 5-40 cm, suckering; fls purple. In sand, in tall open-heath.			
Solanum orbiculatum Dun. Solanaceae .... Spreading shrub to 50 cm; fls pale purple. On sand dune near coast.	X	X	
Spinifex longifolius R.Br. Poaceae ... . Perennial grass, dioecious. On coastal dunes.	X	X	
Sporobolus virginicus (L.) Kunth. Poaceae .... Perennial rhizomatous grass; fls purplish. In sand, in low open-heath near coast.	X	X	
Spyridium complicatum F.Muell. Rhamnaceae .... Rounded shrub to 40 cm, with old fls. In sand, in low open-heath.	X*		
Spyridium? divaricatum Benth. Rhamnaceae .... Small, much-branched shrub. In sand, in low open-heath.	X		
Stackhousia viminea Sm. Stackhousiaceae .... Ephemeral herb; fls yellow. In sand, in tall open-heath.	X	X	
Stenopetalum sphaerocarpum F.Muell. Brassicaceae Ephemeral herb; fls pale yellow. In sand over limestone, in low open-heath.	X*		
Stipa crinita Gaud. Poaceae .... In sand, in open-heath.	X*		
Stipa elegantissima Labill. Poaceae .... Perennial grass.	X	X	
Stipa sp. ASG 11394. Poaceae .... On sand dune by coast, in open-heath and in low open-shrubland.			
Stylobasium spathulatum Desf. Stylobasiaceae .... Shrub to 1 m. In sand, in open-heath.	X		
Swainsona beasleyana F.Muell. subsp. *elegantoides* A.Lee. Papilionaceae .... Ephemeral herb; fls maroon-pink, turning blue, eye pale yellow. In sand over limestone, on sea cliffs.		X	
Swainsona kingii F.Muell. subsp. *kingii*. Papilionaceae Prostrate ephemeral herb; fls maroon. In limestone, in tall open-heath.		X	
Swainsona phacoides F.Muell. subsp. *graudiflora* (Benth.) A.Lee. Papilionaceae .. .. Prostrate ephemeral herb, scapes erect; fls maroon, turning blue, eye yellow. In sand, in low open-heath.		X	
Swainsona sp. ASG 11570. Papilionaceae .... Prostrate ephemeral herb; fls pink. In limestone, in tall open-heath.			
Tetragonia anuplexicoma (Miq.) Hook.f. Aizoaceae Straggling shrub. fls yellow. In sand, in tall open-heath.	X*		
Tetragonia diptera F. Muell. Aizoaceae .... Ephemeral herb. In sand at base of low cliff.		X	X
Threlkeldia diffusa R.Br. Chenopodiaceae .... Diffuse perennial herb, lvs succulent. In sand by homestead.	X	X	
Thryptomene baeckeacea F.Muell. Myrtaceae .... Sprawling shrub to 50 cm tall x 1 m broad; fls pink. Common, in sand and limestone, in tall and low open-heath.		X	
Thysanotus patersonii R.Br. Liliaceae .... Twining herb with tubers, fls pale purple. In sand over limestone, in tall open-heath.	X	X	
Thysanotus speckii Brittan. Liliaceae .... In shelter of shrubs, in sand in low very open-heath.		X	
Trachymene elachocarpa (F.Muell.) B. L. Burtt. Apiaceae .... Ephemeral herb; fls white. In sand, in low open-heath.	X		
Trachymene aff. *pilosa* Sm. Apiaceae . . Tiny ephemeral herb; fruit ± smooth. In sand, in open-heath.			
Tribulus occidentalis R.Br. Zygophyllaceae . Near homestead.		X	
Trichodesma zeylanicum (L.) R.Br. Boraginaceae Collected by Milne.		X	
Tricoryne elatior R.Br. Liliaceae ... . Collected by Gaudichaud.	X		
Triglochin calcitrapa Hook. var. *isingiana* Black. Juncaginaceae .... Ephemeral herb. In sand, in open grazed area by mill.	X	X	
Triglochin mucronata R.Br. Juncaginaceae .... Ephemeral herb. In sand, in open grazed area by mill.	X*		
Triglochin trichophora Nees. Juncaginaceae .... Ephemeral herb. In sand, in tall open-heath.	X		
Triodia plurinervata N.T. Burbidge. Poaceae .... Spinifex, in clumps to 40 cm tall x 2 m broad; foliage fine, ± bright green. In sand, in low open/closed-heath with hummock grassland.		X	
Vittadinia sp. Asteraceae .... Ephemeral herb; rays pale mauve, fls yellow. In sand over limestone, in tall open-heath.	X	X	
Wahlenbergia sp. Campanulaceae .... Ephemeral herb; fls pale blue. In sand over limestone, in low open-heath.			
Waitzia citrina (Benth.) Steetz. Asteraceae .... Ephemeral herb; fls yellow. In sand. in tall open-heath.	X	X	
Waitzia podolepis (Gaud.) Steetz. Asteraceae .... Ephemeral herb. In sand, in open-heath.		X	X
Westingia rigida R.Br. Lamiaceae .... Much-branched shrub to 70 cm; fls white. .... In sand, in tall open-heath.	X		
Zygophyllum ammophilum F.Muell. Zygophyllaceae Ephemeral herb. In sand, in low open-heath.		X	
Zygophyllum aurantiacum Lindl. Zygophyllaceae .... Straggling perennial herb; fls pale yellow. In sand, in open-heath.	X	X	
Zygophyllum aff. *aurantiacum* Lindl. Zygophyllaceae Much-branched perennial herb; fls white. On sand dune by coast, in open-heath.			
Zygophyllum aff. *fruticulosum* DC. Zygophyllaceae			

Table 3

Exotic species naturalised on Dirk Hartog Island.

Species	Family	Place of Origin
Anagallis arvensis L. var. *caerulea* Gouan	Primulaceae	Europe
Arctotheca calendula (L.) Levyns	Asteraceae	South Africa
Asphodelus fistulosus L.	Liliaceae	Mediterranean region
Avena barbata Brot.	Poaceae	Mediterranean region
Brassica tournefortii Gouan	Brassicaceae	Mediterranean region
Briza minor L.	Poaceae	Mediterranean region
Bromus diandrus Roth	Poaceae	Mediterranean region
Bromus hordeaceus L.	Poaceae	Mediterranean region
Cenchrus ciliaris L.	Poaceae	Africa/N. India
Cenchrus setigerus Vahl	Poaceae	Africa/N. India
Centaurea melitensis L.	Asteraceae	Europe—W. Asia
Cerastium glomeratum Thuill.	Caryophyllaceae	Europe
Chenopodium murale L.	Chenopodiaceae	Europe
Cynodon dactylon (L.) Pers.	Poaceae	South Africa
Diplotaxis muralis (L.) DC.	Brassicaceae	Europe
Ehrharta brevifolia Schrad.	Poaceae	South Africa
Emex australis Steinh.	Polygonaceae	South Africa
Erodium cicutarium (L.) L.Her. ex Ait.	Geraniaceae	Europe—S. Asia
Hordeum leporinum Link.	Poaceae	Mediterranean region
Hypochoeris glabra L.	Asteraceae	Europe—Asia
Koeleria phleoides (Vill.) Pers.	Poaceae	Mediterranean region
Lavatera cretica L.	Malvaceae	Mediterranean region
Lolium loliaceum (Bory et Chaub.) Hand-Mazz.	Poaceae	Mediterranean region
Medicago polymorpha L. subsp. *polymorpha*	Papilionaceae	Mediterranean region
Melilotus indicus (L.) All.	Papilionaceae	Europe—W. Asia
Nicotiana glauca R. Graham	Solanaceae	Argentina
Poa annua L.	Poaceae	Europe—W. Asia
Polycarpon tetraphyllum (L.) L.	Caryophyllaceae	Europe
Ricinus communis L.	Euphorbiaceae	India—tropical Africa
Silene gallica L.	Caryophyllaceae	Europe
Sisymbrium irio L.	Brassicaceae	Mediterranean region
Sisybrium orientale L.	Brassicaceae	Mediterranean region
Solanum nodiflorum Jacq.	Solanaceae	N. & S. America
Sonchus oleraceus L.	Asteraceae	Europe—Asia
Spergularia rubra (L.) J. & C. Presl.	Caryophyllaceae	Europe
Urospermum picroides (L.) Desf.	Asteraceae	Mediterranean region

cymosa and *Brachysema macrocarpum*. Of the three dominant species on the island—*Acacia ligulata, Thryptomene baeckeacea* and *Plectrachne* sp.—the *Acacia* and *Thryptomene* extended well into the South West Province while the *Plectrachne*, though of a typical Eremean genus, is restricted to the island and Edel Land and is marginally Eremean. Several major families which characterise the South West Province are lacking (e.g. Epacridaceae, Droseraceae, Dilleniaceae) or poorly represented (e.g. Proteaceae [1 sp.], Orchidaceae [1 sp.], Haemodoraceao [1 sp.]).

If life-form is considered, it can be seen that the woody shrubs are more South Western than Eremean, while the ephemeral herbs are predominantly Eremean. Of the 77 purely South West species on the island, 42 are shrubs or perennial herbs, while of the 61 Eremean only 24 are shrubs or perennial herbs.

Vegetation formation (physiognomy) presents no clearer picture. The widespread open-heath can be considered intermediate, though similar formations but lacking *Triodia* or *Plectrachne* occur near the coast between Tamala and Kalbarri to the south of Shark Bay.

It is clearly difficult to place Dirk Hartog Island in either Province, and it may be best left in a "Transitional zone". However if placed in one or the other the South West Province is preferable because

1. a majority of the species present are either South Western or have strong South Western affinities;
2. the vegetation formations, apart from hummock grassland, are more representative of the South West than the Eremean.

Naturalised flora

Table 3 lists 36 introduced species which are considered naturalised. The country of origin is given after the family. Most have their origin in Europe (especially the Mediterranean region) or South Africa. Several grasses have probably been introduced as pasture species, e.g. *Cenchrus ciliaris, C. setigerus* and *Bromus diandrus*. The others have probably come to the island with sheep. All are common weeds of south western Australia except the two *Cenchrus* species. There are 12 Poaceae, 5 Asteraceae, 4 Brassicaceae, 4 Caryophyllaceae, 2 Papilionaceae, 2 Solanaceae and 1 each of seven other families. Thirty are ephemeral herbs, 4 are perennial and 2 are shrubs.

Fauna

Mammals

Lagostrophus fasciatus (Péron). Banded Hare-wallaby.—This species was first described by Péron in 1807. He reported it as being very common on Dirk Hartog as well as on Bernier

and Dorre Islands. It is presumably the wallaby seen by William Dampier in 1699 (Dampier 1729, p. 85).

L. fasciatus is known only from the South west of Western Australia and its northern limit is Bernier Island. To-day there is little doubt that this species is extinct on Dirk Hartog as well as on the mainland. It survives only on Bernier and Dorre Islands. Local knowledge from the Shark Bay area puts the date of extinction of the "wallabies" (possibly including the two species below) in the 1920s. It must have been some time ago since we did not locate any skeletal remains. It is perhaps pertinent that Shortridge (1909, p. 818) stated that ". . . in the south of Dirk Hartog there is a large sheep station and the wallabies are said to have entirely left that end of the island".

Following our 1972 visit the Western Australian Wildlife Authority and Sir Thomas Wardle agreed on a programme, to be carried out by the Western Australian Wildlife Research Centre, to attempt the re-introduction of the Banded Hare-wallaby to Dirk Hartog Island. In April 1974 11 adult animals (4 male, 7 female, 6 with small pouch young) which had been captured on Dorre Island were placed in two pens on Dirk Hartog. By December, 1976, the breeding colony had increased to 33 adults and 3 dependent young. An attempt to reduce feral cat numbers (see below) is under way, and the first releases of wallabies to the wild took place during May 1977.

Knowledge of the biology of *Lagostrophus* is summarised by Ride and Tyndale-Biscoe (in Ride *et al.* 1962) and Tyndale-Biscoe (1965).

Lagorchestes hirsutus (Gould). Western Hare-wallaby.—This wallaby occurs on Bernier and Dorre Islands but is very rare on the mainland. While some authors have noted that it occurred or probably occurred on Dirk Hartog (e.g. Shortridge 1909; Glauert 1933; Main 1961; Main and Yadav 1971) it appears that no specimen has been collected and some doubt must remain that it ever existed there.

Bettongia lesueur (Quoy & Gaimard). Boodie.—The Boodie was first collected as a skull picked up on Dirk Hartog by Freycinet's Expedition (Quoy and Gaimard 1824). They obtained no entire animals but caught glimpses of an animal that lived in burrows and foraged in the debris on the beaches at night. This description fits that of *B. lesueur*, but not of any of the hare wallabies. No specimen has since been collected on Dirk Hartog.

The Boodie once had a wide distribution in the southern two thirds of Australia. It appears to be extinct on the mainland and is now confined to Barrow, Boodie (a small island south of Barrow), Bernier and Dorre Islands. We saw no sign of it during our visits.

Perameles bougainville (Quoy & Gaimard). Marl.—This bandicoot is common on Bernier and Dorre Islands, but has not been collected on Dirk Hartog. It was first collected on Peron Peninsula by Quoy and Gaimard and the Western Australian Museum has a single specimen from Onslow which was collected in 1909. The only possible reference to this species on Dirk Hartog is the sighting of a "small opossum" on the island by A. C. Cunningham, the botanist with King's expedition in 1821 (King 1827). This has been interpreted by Alexander (1915, p. 123) as being a reference to *Perameles bougainville*. We saw no evidence of it during our visit.

Pseudomys hermannsburgensis (Waite). Sandy Mouse.—Nine specimens have been taken from the island. Four were from a trapline located 10 km south of the homestead. This area consists of deep white sand with occasional limestone outcrops and the vegetation is an *Acacia* low shrubland mixed with spinifex (*Plectrachne* sp.). One was from an *Acacia* thicket at the base of a dune 13 km south of the homestead. Two came from red sand near Sandy Point outcamp where the vegetation is a tall shrubland of *Acacia ligulata*, *Alyogyne cuneiformis* and *Thryptomene baeckeacea* with spinifex (*Plectrachne* sp.) as a scattered ground cover. One specimen from Sandy Point was taken during September 1972, the remainder in April 1974. A. G. Wells collected two specimens at Herald Bay in September 1973. The species has not previously been recorded from Dirk Hartog. It has a wide distribution in the dry parts of the interior (Ride 1970) and is also known from Rosemary Island (Burbidge and Prince 1972).

Pseudomys albocinereus (Gould). Ashy-grey Mouse.—Two specimens were taken, both in April 1974, at a location 10 km south of Dirk Hartog homestead. The soil and vegetation are described above under *P. hermannsburgensis*. This species was also previously unknown from Dirk Hartog. It occurs on Bernier and Dorre Islands, and on the mainland in various sandplain habitats in the south-west.

Mus musculus (Linnaeus). House Mouse.—Nine specimens have been collected, two in September 1972 and the remainder in April 1974. This species was present in all habitats which were trapped and occurs commonly around the homestead.

Nyctophilus geoffroyi (Leach). Lesser Long-eared Bat.—In September 1972, one specimen was captured by hand as it was flying out of a cave in the cliffs on the western side of the island near West Coast Mill. The species has a wide distribution.

Eptesicus pumilis (Gray). Little Bat.—Two specimens were taken in April 1974. One was collected at Sandy Point Outcamp and the other in a cave near West Coast Mill. The species has a wide distribution.

Capra hircus (Linnaeus). Goat.—We saw about 140 goats during the 1972 visit. Four flocks were seen; one of 56, one of about 50 and two of 20. At the time station hands estimated that there were about 700 goats on the island. Our observations suggest that this figure may be conservative.

The domestic goat turned feral is now a common animal in many parts of Western Australia and the damage which it is doing to the

vegetation is only beginning to be appreciated by pastoralists and the general public. On Bernier Island goats were introduced in 1899 and extensive damage has been done to the vegetation. Air photographs show that the number and extent of sand dune blowouts have increased greatly over the past 20 years. Following the recommendations of a party of scientists who visited the island in 1959 (Ride *et al.* 1962) the Department of Fisheries and Wildlife carried out a campaign of attack on the goats and by 1972 more than 450 had been shot. We estimate that at the commencement of shooting in 1959 Bernier Island carried about 350 goats, or 1 goat to 12 ha. With a similar density Dirk Hartog could support a population of about 5 000.

However, on Dirk Hartog goat density is affected by two factors not present on Bernier. These are the presence of drinking troughs which may allow an even greater density, and competition for food from sheep. Sheep numbers in the past have been over 10 000 (see below) and this may have kept goat numbers down. However, goats tend to browse shrubs much more than do sheep and would not always be in direct competition for food.

Damage to vegetation by sheep and goats on Dirk Hartog was obvious but it did not appear to be worse than that on Bernier Island except where heavy overgrazing had occurred near drinking troughs.

Following the 1972 visit we voiced our concern about goats to Sir Thomas Wardle and he responded by placing a bounty on them. About 800 were destroyed during the following two years.

Ovis aries (Linnaeus). Sheep.—Dirk Hartog has been used as a sheep station since 1899. The number of sheep on the island has usually been between 10 000 and 11 000. In 1972 the population was only about 4 000 and only the southern two-thirds of the island was stocked.

Equus caballus (Linnaeus). Horse.—During our 1972 visit we were told that there were about 12 horses on the island, all mares.

Camelus dromedarius (Linnaeus). Camel.—Carter (1917) records that during his visit camels were used to take rations to men stationed at outcamps and windmills. There are no camels on the island at present.

Felis catus (Linnaeus). Domestic Cat.—The domestic cat is well established on Dirk Hartog. Although sightings of the animal itself were infrequent, tracks were seen all over the island.

It is not known when the species became established but it seems probable that cats were taken to the island when the sheep station was established. Carter (1917, p. 605) states that "cats . . . are now becoming numerous on the island".

Feral cats are common and widespread on the Australian mainland. They are also known from three other islands off the west coast—Trimouille and Hermite islands in the Monte Bello group and Rottnest Island near Perth. On Hermite they have apparently been responsible for the disappearance of two species of marsupials and two species of birds (Burbidge 1971). These are the Spectacled Hare-wallaby *(Lagorchestes conspicillatus)*, Golden Bandicoot *(Isoodon auratus)*, Black and White Wren *(Malurus leucopterus)* and Spinifex-bird *(Eremiornis carteri)*. On Rottnest Island the cats have been reduced in number by poisoning programmes.

Two cats shot near the homestead in April 1974 had a variety of materials in their stomachs. In both a large centipede predominated but one had the remains of a Zebra Finch and the gecko *Gehyra variegata* while the other contained remains of a Silver Gull.

Dugong dugon (Lacépède). Dugong.—Shark Bay is considered to be the southern limit of the range of this species on the west coast, although occasional animals have been sighted further south, for example off Geraldton. On 3 September 1972, we saw between 30 and 40 Dugong feeding in shallow water adjacent to Quoin Bluff South. One or two are often seen near the homestead.

Neophoca cinerea (Péron & Lesueur). Australian Sea Lion.—King (1827) records that Cunningham, the botanist accompanying his expedition, saw a Sea Lion on Dirk Hartog Island in 1821. Local knowledge indicates that this species is occasionally found in Shark Bay, although the northern limit of its distribution is usually the Abrolhos Islands.

Mammalian Sub-fossil Material.—Because of the lack of evidence regarding the presence of *Lagorchestes hirsutus* and *Perameles bougainville* we arranged for Dr D. Merrilees and Mr A. Baynes of the Western Australian Museum to visit the island and collect sub-fossil material. During a short visit in April 1974 they excavated cave deposits at Herald Heights and Notch Point with the following results (Merrilees and Baynes, pers. comm.).

Herald Heights
- *Sminthopsis* cf. *murina*
- *Antechinus apicalis*
- *Dasycercus cristicauda*
- *Perameles bougainville*
- *Bettongia lesueur*
- *Bettongia penicillata*
- *Leporillus conditor*
- *Pseudomys hermannsburgensis*
- *Pseudomys shortridgei*
- *Pseudomys praeconis*
- *Pseudomys* sp.

Notch Point
- *Dasyurus geoffroii*
- *Perameles bougainville*
- *Bettongia lesueur*
- cf. *Pseudomys praeconis*

The *Pseudomys* sp. from Herald Heights is not *P. albocinereus* but is larger and might be *P. desertor*. It can be seen that although *Perameles* did occur on Dirk Hartog at some time the deposits did not yield remains of *Lagorchestes*. This does not prove that *Lagorchestes* did not

occur there. With the exception of the *Bettongia* spp., all the above are comparatively small animals and the deposits may have been accumulated by owls or other similar-sized predators. *Bettongia lesueur* live in burrows and could have made their own way into these caves. There are no *Lagostrophus* in the deposits, and it and the similarly sized *Lagorchestes* may have been too large to be taken by the predator concerned.

In April 1974, W. K. Youngson found what appeared to be the sub-fossil remains of an owl pellet deposit in a cave near the ocean adjacent to West Coast Mill. This deposit contained remains from the following species: *Perameles bougainville, Dasyurus geoffroii, Dasycercus cristicauda, Sminthopsis* cf. *murina, Leporillus conditor, Pseudomys hermannsburgensis, P. praeconis, P. shortridgei* and *Nyctophilus geoffroyi.*

Birds

Observations on the birds of Dirk Hartog Island have been the subject of a number of publications over the years, including Carter (1917, 1923), Whitlock (1921), Ashby (1927), Sedgwick (1968), Wells and Wells (1974) and Davies and Chapman (1975). The last of these provides a comprehensive summary of the observations of previous authors and lists some 77 species for the island, four of which are seabirds listed as "off Dirk Hartog". To this we can add 7 species—*Anas gibberifrons* (Grey Teal), *Tringa brevipes* (Grey-tailed Tattler) seen in April 1972, *Nymphicus hollandicus* (Cockatiel) seen in April 1974, *Calidris canutus* (Knot), *Sterna dougallii* (Roseate Tern), *S. bengalensis* (Lesser Crested Tern) and *Cheramoeca leucosternum* (White-backed Swallow) seen in December 1976. Tattlers were also plentiful at the time of this visit. We also observed a single Rock Dove or Domestic Pigeon (*Columba livia)* on the island in 1972. This was a stray racing pigeon, carrying a Pigeon Racing Federation band. Wells and Wells (1974) recorded another racing pigeon in 1973. From Davies and Chapman's Appendix 5—Species not seen since 1921—we can remove Large Sand Dotterel (seen in 1972 and 1976), Greenshank (1974 and 1976), Bar-tailed Godwit (1972 and 1976) and Little Wood Swallow (1972).

* *Pelecanus conspicillatus*	Australian Pelican
* *Phalacrocorax varius*	Pied Cormorant
* *Egretta sacra*	Reef Heron
† *Tadorna tadornoides*	Mountain Duck
* *Anas gibberifrons*	Grey Teal
Accipiter fasciatus	Australian Goshawk
* *Accipiter cirrocephalus*	Collared Sparrowhawk
* *Aquila audax*	Wedge-tailed Eagle
Hieraactus morphnoides	Australian Little Eagle
* *Haliaeetus leucogaster*	White-breasted Sea Eagle
Circus assimilis	Spotted Harrier
* *Pandion haliactus*	Osprey
* *Falco cenchroides*	Nankeen Kestrel
Falco berigora	Brown Falcon
Turnix varia	Painted Quail
Rallus philippensis	Banded Landrail
* *Eupodotis australis*	Australian Bustard
* *Haematopus ostralegus*	Pied Oystercatcher
* *Haematopus fuliginosus*	Sooty Oystercatcher
* *Vanellus tricolor*	Banded Plover
Peltohyas australis	Australian Dotterel
* *Charadrius alexandrinus*	Red-capped Dotterel
* *Charadrius leschenaulti*	Large Sand Dotterel
† *Pluvialis squatarola*	Grey Plover
* *Arenaria interpres*	Turnstone
† *Numenius phaeopus*	Whimbrel
† *Numenius madagascariensis*	Eastern Curlew
† *Tringa nebularia*	Greenshank
Tringa hypoleucos	Common Sandpiper
* *Tringa brevipes*	Grey-tailed Tattler
† *Calidris canutus*	Knot
* *Calidris acuminata*	Sharp-tailed Sandpiper
* *Calidris ruficollis*	Red-necked Stint
* *Limosa lapponica*	Bar-tailed Godwit
* *Himantopus himantopus*	White-headed Stilt
* *Burhinus magnirostris*	Southern Stone-Curlew
* *Larus pacificus*	Pacific Gull
* *Larus novaehollandiae*	Silver Gull
* *Hydroprogne caspia*	Caspian Tern
† *Sterna dougallii*	Roseate Tern
Sterna nereis	Fairy Tern
* *Sterna bergii*	Crested Tern
† *Sterna bengalensis*	Lesser Crested Tern
Geopelia cuneata	Diamond Dove
Phaps chalcopiera	Common Bronzewing
Cacatua sanguinea	Little Corella
Cacatua roseicapilla	Galah
† *Nymphicus hollandicus*	Cockatiel
Neophema petrophila	Rock Parrot
Cuculus pallidus	Pallid Cuckoo
Chrysococcyx basalis	Horsfield Bronze Cuckoo
Ninox novaeseelandiae	Boobook Owl
Eurostopodus guttatus	Spotted Nightjar
† *Cheramoeca leucosternum*	White-backed Swallow
* *Hirunda neoxena*	Welcome Swallow
Petrochelidon nigricans	Tree Martin
* *Anthus novaeseelandiae*	Australian Pipit
Coracina novaehollandiae	Black-faced Cuckoo-Shrike
Cinclorhamphus cruralis	Brown Songlark
* *Malurus leucopterus*	Black-and-white Wren
* *Malurus lamberti*	Variegated Wren
* *Stipiturus malachurus*	Southern Emu-Wren
* *Sericornis maculatus*	Spotted Scrub-Wren
* *Calamanthus fuliginosus*	Field-Wren
Amytornis textilis	Western Grass-Wren
* *Ephthianura albifrons*	White-fronted Chat
Ephthianura tricolor	Crimson Chat
Petroica goodenovii	Red-capped Robin
Petroica cucullata	Hooded Robin
* *Rhipidura leucophrys*	Willie Wagtail
Oreoica gutturalis	Crested Bell-Bird
Dicaeum hirundinaceum	Mistletoe Bird
* *Zosterops gouldi*	Western Silvereye
Lichmera indistincta	Brown Honeyeater
* *Meliphaga virescens*	Singing Honeyeater
* *Poephila guttata*	Zebra Finch
Grallina cyanoleuca	Magpie-Lark
* *Artamus cinereus*	Black-faced Wood-Swallow
* *Artamus minor*	Little Wood-Swallow
* *Cracticus torquatus*	Grey Butcher-Bird
* *Corvus bennetti*	Little Crow

A full list of those species known from the island follows. Those birds observed by us in 1972 are marked with an asterisk and additional species seen by us since 1972 with a dagger.

The avifauna of Dirk Hartog Island does not comprise a large number of species but it does show some interesting differences from that of Peron Peninsula, immediately to the east. Wrens are much more common on the island. Indeed Carter (1917, p. 571) suggested that "Dirk Hartog might be called an island of Wrens, as at least ninety of every hundred land-birds seen are Wrens". On the other hand a number of common arid zone species which occur on Peron Peninsula are uncommon or absent on the island, e.g. Crested Pigeon, Wedgebill, Pallid Cuckoo and Crested Bell-Bird. Davies and Chapman (1975) suggest that this could be due to some species having only recently arrived in the area. It could also be due to the difference in soils and vegetation—Peron Peninsula has a vegetation similar to much of the Murchison (Beard 1976) while Dirk Hartog has no Bowgada (*Acacia ramulosa*) and has a less dense shrub layer and more heath-like formations. Dirk Hartog's avifauna will probably prove to be more akin to the mainland south of the island (Edel Land) which has a similar vegetation.

Most species recorded from Dirk Hartog have wide-ranging distributions and many, e.g. the Zebra Finch, Little Crow and Little Wood-Swallow are typical of the arid zone. However, two southern species, the Rock Parrot and the Southern Emu-Wren occur here at the northern end of their range. The Spotted Scrub-Wren extends northward only as far as Bernier and Dorre Islands. Other species close to the northern end of their range are the Western Silvereye and White-fronted Chat. The Black-and-white Wren is of special interest, being restricted to Dirk Hartog and Barrow Islands.

On 3 September 1972 we inspected the nesting colony of Pied Cormorants at Quoin Bluff South. We estimated the number of nests at about 2 500, the same figure reached by Whitlock in 1920. Only about 1% contained eggs; most contained half grown young.

Other birds which were breeding during this visit included Grey Teal (young almost fully fledged), Nankeen Kestrel (eggs), Caspian Tern (one nest with 2 eggs on Cape Ransonnet), Crested Tern (one chick on Meade Island), White-breasted Sea Eagle (a chick in a nest at Quoin Bluff South), Osprey (several nests, both eggs and chicks present), Banded Plover (a nest at Two Wells Mill, one young almost fully fledged near Bottom Ten Mile Mill) and Little Crow (several nests; one we inspected had 6 eggs, another at Cape Inscription had newly hatched chicks).

On 9 December 1976 we found a Roseate Tern colony of between 200 and 300 nests on the northern tip of Meade Island which is adjacent to the Homestead and joined to Dirk Hartog Island at low tide. Most nests had one egg, 2 to 3% had two eggs and in about 5% the eggs had recently hatched. Over 500 terns were sighted in the vicinity; between 5 and 10% were in juvenile plumage.

Reptiles

The following species have been collected from Dirk Hartog Island and specimens are lodged in the Western Australian Museum.

GEKKONIDAE
- *Crenadactylus ocellatus horni* (Lucas & Frost)
- *Diplodactylus spinigerus* Gray
- *Diplodactylus vittatus* Gray
- *Gehyra variegata* (Duméril & Bibron)
- *Heteronotia binoei* (Gray)
- *Nephrurus levis occidentalis* Storr
- *Phyllurus mili* Bory

PYGOPODIDAE
- *Delma nasuta* Kluge
- *Lialis burtonis* Gray
- *Pygopus lepidopodus* (Lacépède)

AGAMIDAE
- *Amphibolurus maculatus maculatus* Gray
- *Amphibolurus minor* Sternfeld
- *Amphibolurus parviceps* (Storr)
- *Amphibolurus reticulatus* (Gray)

SCINCIDAE
- *Cryptoblepharus carnabyi* Storr
- *Ctenotus fallens* Storr
- *Ctenotus lesueurii* (Duméril & Bibron)
- *Ctenotus youngsoni* Storr
- *Egernia stokesii badia* Storr
- *Lerista elegans* (Gray)
- *Morethia lineoocellata* (Duméril & Bibron)
- *Lerista lineopunctulata* (Duméril & Bibron)
- *Lerista praepedita* (Boulenger)
- *Omolepida branchialis* (Günther)
- *Tiliqua rugosa* (Gray)

VARANIDAE
- *Varanus gouldii* (Gray)

ELAPIDAE
- *Demansia olivacea* (Gray)
- *Demansia reticulata* (Gray)
- *Pseudechis australis* (Gray)
- *Vermicella littoralis* Storr

HYDROPHIIDAE
- *Hydrophis elegans* (Gray)
- *Hydrophis major* (Shaw)

Ours were the first extensive collections of reptiles made on Dirk Hartog Island. In general the species present are typical of the warmer and drier parts of south-western Australia. The only northern element is the gecko *Nephrurus levis*, which, however, extends as far south as Geraldton.

The skink *Ctenotus youngsoni* is restricted to the Shark Bay area, being known only from Dirk Hartog and the northern part of Edel Land.

Invertebrates

No systematic collecting of invertebrates was attempted. On 29 April 1974, W. K. Youngson collected a sample of humic soil from near Sandy Point from which five species of land snail were obtained. These were *Westralaoma* sp., *Themapupa* sp., *Australbinula* sp., *Austrosuccinea* sp. and *Bothriembryon* sp. Publications on invertebrates from Dirk Hartog include Ashby (1929), Hale (1929) and Allender (1969).

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New data on the origin and distribution of Western Australian sand fulgurites

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Abstract

Lechatelierite fragments totalling 1 084 g, part of a large sand fulgurite, have been recovered from Black Point, Western Australia. Black to very dark brown, altered, woody material plugged the lumen of many tubular fragments when collected. Finely macerated woody material from the fulgurite shows fibrous and cellular structure under the microscope, is anisotropic, and brown to orange. The mean refractive index of the woody material ranges from 1.574±0.002 to 1.598±0.002, but most of it is close to 1.579 ± 0.002. The evidence indicates that the Black Point fulgurite formed around a root. Whether this is a common mode of formation for fulgurites is still open to question, for roots are not necessary for the development of the tubular shape typical of fulgurites.

Lechatelierite tubes are also recorded from west Willetton in the Perth Metropolitan Area, and Mica Hill near Manjimup.

Sand fulgurites have now been recorded from the north of Western Australia almost to its extreme south, but their apparent concentration in the south-west is probably a function of population distribution. Fulgurites are likely to be found in all sandy desert areas of Western Australia, particularly in the north where lightning frequency is high.

Introduction

Sand fulgurites have been recorded from numerous localities in Western Australia, particularly in the south-west (Simpson 1931; Glover 1974, 1975). Most Western Australian fulgurites are represented by a few small fragments of lechatelierite (silica glass) and some by only one piece. Larger collections have been made in the Perth Metropolitan Area from Willetton (500 fragments, totalling about 100 g) and Beechboro (250 fragments, 92 g). The recent recovery of a fulgurite from Black Point (Fig. 1) is of special interest because it is made up of many large tubes containing altered woody material, evidently the remains of a pre-existing root. The possibility that sand fulgurites have formed around roots has been considered by several authors (Lewis 1936, Fenner 1949, Schonland 1964, Trendall 1964) but undoubted field evidence of genetic association has not been adduced. Another point of interest about the fulgurite from Black Point is the large weight of lechatelierite recovered, 1 084 g.

Fulgurite tubes from two other localities, namely west Willetton, and Mica Hill, near Manjimup, are recorded.

Lechatelierite from the Black Point fulgurite is stored in the Western Australian Museum (Nos. G13408 to G13410 inclusive) and the Geology Department, University of Western Australia (Nos. 84672 to 84675 inclusive). Woody material from the Black Point fulgurite (No. 82871) and lechatelierite from the west Willetton fulgurite (No. 82872) are stored in the Geology Department, University of Western Australia.

The Black Point fulgurite

Microscopic appearance

The Black Point fulgurite was found on 20 March 1977 by Mr George Gardner, Mrs Linda Ronk and Mr Alan Ronk near the western edge of a sand blow-out 1 km north-east of Black Point (Pemberton 1:250 000 map, Series R502, S1 50-10, co-ordinates 354749). When in place it consisted of a fragmented tubular body branching downward into five main off-shoots which decreased in diameter with depth. The branches ended 4 or 5 cm below the waterlogged sand, that is, a little more than 1 m below the surface.

A few fragments from the tops of the branches are quite large. One flattened tubular piece with prominent flanges roughly parallel to its length is 20.5 cm long, up to 6.5 cm wide and about 1.5 cm thick (Fig. 2, left). Other fragments are not flattened in one plane, but are twisted rather irregularly (Fig. 2, right). Frag-

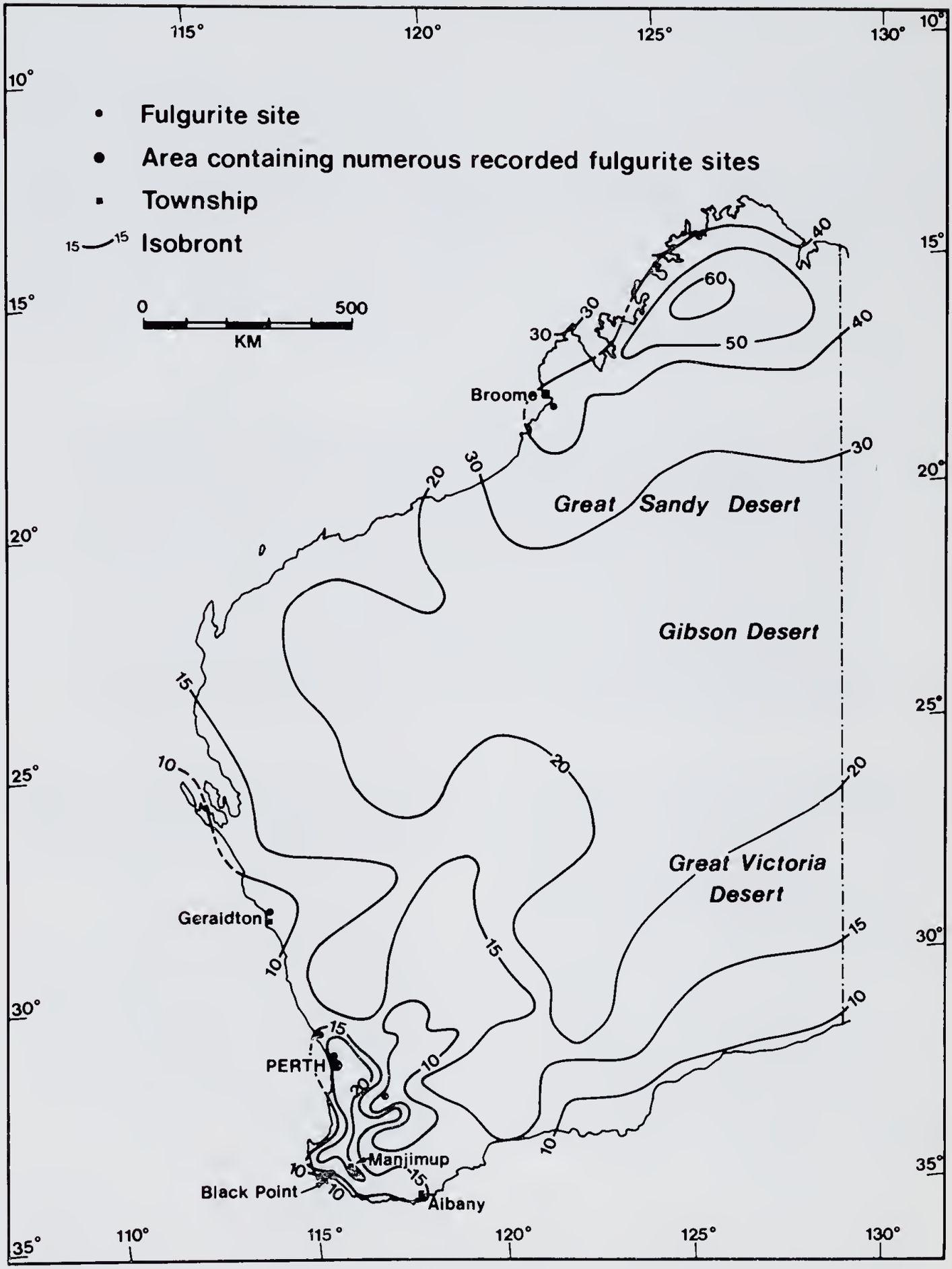

Figure 1.—Average annual thunder day map of Western Australia showing fulgurite sites. The large solid circle around Perth includes 9 separate fulgurite sites, and it is evident that fulgurite recovery is related to population density, and does not reflect the probable distribution of fulgurites. Isobronts after Commonwealth Bureau of Meteorology (1967).

Figure 2.—Two large fragments from the top of the Black Point fulgurite. The fragment on the left is highly flanged, and is flattened in the plane of the photograph. The fragment on the right is flattened in several planes, as though twisted. Scale in cm.

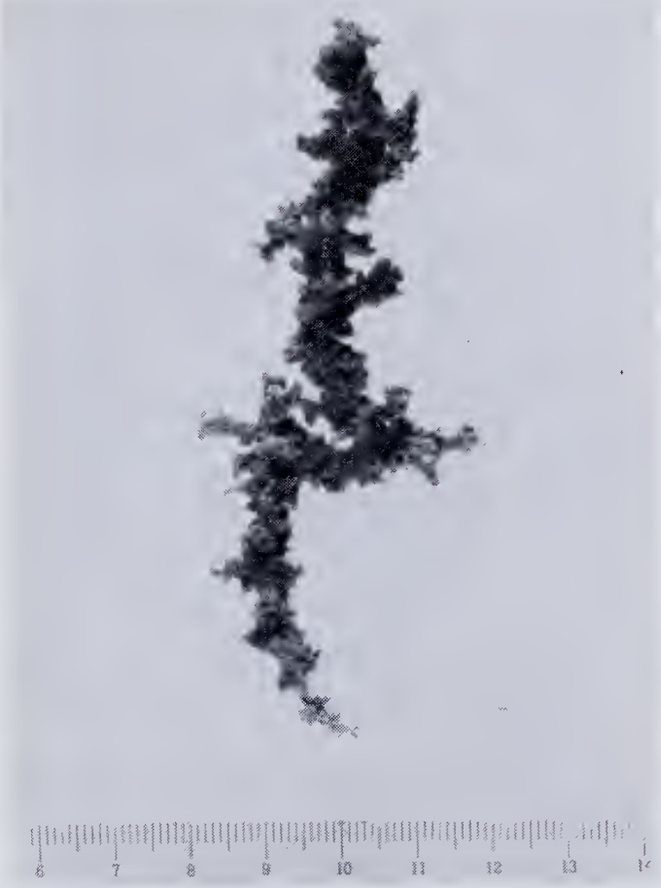

Figure 3.—Fragile fragment from the bottom of a branch of the Black Point fulgurite. Scale in cm.

ments from near the end of branches are thin and fragile, with numerous projections (Fig. 3). The inside of the tube, known as the lumen, is up to 1 cm in diameter in large fragments (Fig. 4), but is commonly flattened or triangular in cross-section. The tube walls of lechatelierite range from about 0.5 to 1 mm in thickness.

The rough, dull, outer surface of the fragments is made up of sand grains embedded in the glass, and contrasts with the shiny, smooth and somewhat mammilated glass on the inside. The outer surface ranges from very light grey (N8) to medium dark grey (N4), but is generally very light grey to light grey (N7) (See Rock-color Chart Committee 1963 for colour terms and accompanying numerical designation). Locally, the outer surface has orange or brownish hues, and material from the water-logged section is mainly very pale orange (10YR8/2) to pale yellowish brown (10YR6/2). The colour of the inner surface ranges from light grey (N7) to black (N1). The black or dark portions of the glass are irregularly shaped, range from less than 1 mm to several mm in diameter, and constitute about 30% of the glass. They commonly merge insensibly into the light grey glass.

Microscopic appearance

Under the microscope most of the lechatelierite is colourless but there are irregularly shaped brown portions corresponding to the black material of the hand-specimen. The refractive index of the colourless glass is between 1.459 and 1.464 $\pm$ 0.002, and is generally close to 1.461 $\pm$ 0.002. Brown glass is commonly higher in refractive index, and some of the light brown (5YR6/4) glass is about 1.467 $\pm$ 0.002. A few small, intensely coloured portions are harder to measure, but their index is higher still, and seems close to 1.475. Colourless and brown glass are both highly vesicular, with bubbles from 0.01 to 0.3 mm in diameter.

Sand grains embedded in the outer surface of the fulgurite are commonly partly coated with opaque mineral, apparently mainly iron oxide. Many grains are partly converted to glass: they are highly cracked on the outside, and commonly pass, via an altered, brownish, finely fibrous portion, into the glass of the fulgurite wall. This texture shows clearly that the fulgurite formed from fusion of sand grains.

Chemistry

The fulgurite contains little carbon, and a total carbon analysis by combustion on 1 g showed 0.01%C.

Figure 4.—Surface fragment of the Black Point fulgurite showing the lumen. Note the contrast between the smooth, shiny, black and grey inner surface, and the rough, dull, grey, exterior. Scale in cm.

Two black and two colourless portions of glass were analysed with the electron microprobe for SiO_2, TiO_2, Al_2O_3, FeO, MgO, CaO and K_2O. One of the black portions recorded 1.93% TiO_2 and 0.66% FeO, and the other 0.14% FeO. Apart from SiO_2, which virtually composes the remainder of the dark material, and forms practically 100% of the clear portions, no other oxide is present in more than trace amount.

Part of the fulgurite was crushed, and separated as far as possible by handpicking into dark and light portions. The separated portions were analysed by fusion (the method of Norrish and Hutton 1969) and comparison by XRF with USGS standards. Results for titanium and iron are as follows:

	TiO_2%	FeO%
Dark material	0.226	0.218
Light material	0.097	0.279

The combined microprobe and XRF results show that some dark areas are significantly enriched in TiO_2, but the distribution and role of iron is uncertain. In general, the chemistry indicated by these partial analyses accords with what might be expected from Table 1, which shows that sand near the bottom of the fulgurite is mainly quartz (about 99.4%) with about 0.4% of the titanium-rich heavy minerals ilmenite and leucoxene.

Altered woody material

Sand and altered woody material were found in the lumen of tubes from all parts of the fulgurite. About 7 g of black to dusky brown (5YR2/2) woody matter were recovered for examination. A few of the pieces are 1 cm or more long and over 0.5 cm wide, and plugged the part of the lumen they occupied. They are unlikely to have fallen in, and therefore apparently preceded the fulgurite. The material is partly soluble in weak alkali, giving a brown supernatant liquid indicating the presence of humic acids.

Macerated woody material examined in oils under the polarizing microscope ranges from black and opaque, where coarse, through moderate reddish brown (10R4/6) to yellowish orange (10YR7/6) where sufficiently fine. Elongate fragments are commonly fibrous or have rather irregular structure, and some fragments are fairly homogeneous in appearance. A few pieces show well-developed cells from 8-13 μm in diameter, the cell walls being 1-1.5 μm thick. The material is anisotropic with low birefringence, and ranges in mean refractive index between 1.574 and 1.598 $\pm$ 0.002, with most readings in the narrow interval between 1.575 and 1.583 $\pm$ 0.002. These figures are toward the lower part of the range of 1.55-1.75 found by Pflug (1954) for lignite humites, and taken together with the presence of humic acids, seem to put the material near the peat-lignite boundary.

Petrography of surrounding sand

A sample of sand from around the bottom of the fulgurite was sieved and weighed. The sand is medium-grained (M=0.28 mm), fairly well sorted (So = 1.37), and consists mainly of quartz. Most grains near the median size are rounded, according to the terminology of Pettijohn (1975, p. 57).

About 95% of the quartz grains are clear, the remainder being cloudy because of numerous minute indeterminate inclusions. Some of the clear grains contain inclusions of opaque mineral, zircon, or tourmaline. The mineral weight % of the sand, obtained from combining grain counts of the weighed size fractions and separated heavy minerals, is shown in Table 1. Three hundred grains from each fraction were counted. Heavy minerals, of which ilmenite is the main constituent, make up only 0.4% of the sand.

Table 1

Weight % of minerals in sand near the bottom of the Black Point fulgurite

Mineral	Weight %
Quartz	99.38
Ilmenite	0.35
Kaolinized feldspar	0.20
Leucoxene	0.03
Zircon	0.02
Magnetite	0.01
Rutile	Trace
Sillimanite	Trace
Kyanite	Trace
Tourmaline	Trace
Staurolite	Trace
Unknown	Trace

The west Willetton fulgurite

The west Willetton fulgurite was found by Mr R. H. Stranger in a road cutting through sand along Agin Court Drive (Pinjarra 1:250 000 map, series R 502 51 50-2, coordinates 386035). It is a tube 3.0 cm long, with an irregularly shaped, very roughly circular cross-section, ranging in diameter from 0.9 mm to 1.3 mm. Wall thickness ranges from about 0.5 mm to 1.0 mm. The rough, outer surface of the tube is white (N9) to very light grey (N8) and contains embedded, partly fused white sand grains that are commonly rounded and about 0.25 mm in diameter. There are no prominent flanges. The surface of the lumen is shiny, fairly smooth to somewhat mammilated, and very light grey. About 20 small, irregularly shaped black portions up to 1 mm in diameter are scattered throughout the wall. The refractive index of the very light grey glass is 1.461 $\pm$ 0.002.

The Manjimup fulgurite

The Manjimup fulgurite is recorded here to correct a published error of location. The fulgurite, CSIRO No. 9073, is a tube with an unusual lacy texture, and was submitted as coming from Wanneroo about 25 km north of Perth. It has already been described and illustrated (Glover 1975, p. 57). The object is now stated by W. M. McArthur (pers. comm. 1976) to have come from a sandpit at Mica Hill, about 14 km south-east of Manjimup, lat. 34°19'S, long. 116°12'E.

The origin of fulgurite morphology

The origin of lechatelierite previously found in sandy areas of Western Australia has been attributed to fusion of the sand by lightning (Glover 1974). The full argument will not be repeated here. It is enough to say that there are two Australian reports of sand fulgurites collected after observed lightning strikes (Simpson 1931, Fenner 1949, p. 128), and numerous extra-Australian reports (see for example Pfaff 1822, Wicke 1859, Van Bastelaer 1883, Diller 1884, Bayley 1892, Wood 1910, Noe-Nygaard 1973), and that all Western Australian lechatelierite fragments described have the same morphology and mineralogy as the bodies formed by lightning. All are either tubes, or fragments of tube walls or their flange-like extensions. It is still not clear, however, why sand fulgurites adopt a tubular habit.

Rock fulgurites are not recorded in Australia, and are therefore rather neglected in the local literature. Nevertheless, as they commonly take the form of glass-walled tubes within the rock, they should be considered in any argument about the origin of the tubular shape of sand fulgurites. Rock fulgurites seem to be found mainly on mountain peaks subject to lightning strikes. They have been described in a wide range of rock types, notably hornblende gneiss (Rutley 1885), glaucophane schist (Rutley 1889), and serpentine (Aston and Bonney 1896) from the European Alps; andesite from the San Francisco Peaks, Arizona (Davis and Breed 1968) and Little Ararat, Turkey (Switzer and Melson 1972); quartz diorite porphyry from Crested Butte, Colorado (Switzer and Melson 1972); hornfels from Castle Peak, Colorado (Switzer and Melson 1972); trachyte from Nevado de Toluca in Mexico (von Humbolt 1845, reported in Davis and Breed 1968); and siliceous limestone from the Pyrenees (Diller 1884). They have even been reported from streets in Detroit (Hill 1947).

The presence of altered woody material within the Black Point fulgurite suggests that lightning followed down a small root and fused surrounding sand to form lechatelierite. The concept that roots have conveyed current in this way is not new, and has been considered for example by Lewis (1936), who described a fulgurite with an internal surface film of carbon, and by Schonland (1964), Fenner (1949) and Trendall (1964). Bushes or shrubs are quite likely to be struck by lightning, and live roots would be a better conductor than surrounding sand. Nevertheless, roots are not necessary for the development of tubular fulgurites. Some artificial fulgurites are tubular (Petty 1936; Fenner 1949; Schonland 1964) and a tubular sand fulgurite was recovered from a heap of building sand after it was struck by lightning (Van Bastelaer 1883). As mentioned above, many rock fulgurites are also tubular. Conventional theory attributes the lumen in sand fulgurites to thermal expansion of air or water, although a supposed mechanical action of the lightning in forcing the sand apart has also been suggested (see Frondel 1962). Vesicles are presumably caused by expanding gas or vapour. The very low amount of carbon in the Black Point fulgurite accords with the hypothesis that the sand was forced away from the root as it fused. Flattening and deformation of the lumen could be brought about by subsequent sand pressure on the plastic glass.

To sum up, the presence of altered woody matter in the Black Point fulgurite seems to be the firmest evidence found so far that a sand fulgurite has formed around a root. Whether this is a common mode of formation for sand fulgurites is still open to question.

Probable distribution of sand fulgurites in Western Australia

Most Western Australian fulgurites have been recorded from the populous south-west of the State, especially around Perth, and this almost certainly reflects the distribution of observers rather than fulgurites. The fulgurites are generally revealed in deflating areas, where wind has blown away sand and left the lechatelierite fragments.

One of the main factors affecting fulgurite abundance is the frequency of lightning, which is indicated cartographically by lines called isobronts that join places with an equal number of thunder-days in a given period. Nevertheless, isobrontic maps have not proved a reliable guide to the abundance of sand fulgurites, and it is worth considering why this may be. Thunder data are probably insufficient in many countries to produce reliable isobrontic maps, and it is notable that satellite data gathered on the world

distribution of some 7 000 lightning strikes in 1969-70 (Sparrow and Ney 1971) can be reconciled with the current isobrontic maps of some areas only in a fairly general way. However, there are certainly other factors. The thunder recorded on the maps includes an indeterminate proportion caused by cloud-to-cloud lightning, which is obviously irrelevant to any consideration of fulgurite formation. The age of the land surfaces, and the consequent period of their exposure to lightning are important, as are pronounced climatic changes in areas with long-exposed surfaces. The surface should be sandy and not shielded by a dense canopy of vegetation. Local conditions in sandy terrains can play a significant part: for example Lacroix (1931, 1942) emphasizes that Saharan fulgurites are only found near the base of dunes, where sand is moister than on the crest. Fulgurites may be less noticeable in some places because sand movement has broken them into small fragments, or because they are concealed under a growing sand cover. Whatever the combination of reasons, classical African fulgurite localities in the Sahara Desert (Lacroix 1931, 1942) and in the Kalahari Desert (Lewis 1936), show an isobrontic range from 40 to less than 10 (isobrontic data from the map of Griffiths 1972, p. 29). There is a similar situation in Western Australia, where recorded fulgurite localities show an isobrontic range from higher than 40 to less than 10 (isobrontic data from Commonwealth Bureau of Meteorology 1967). It seems that most sandy areas in Western Australia will yield fulgurites, and that they may be especially abundant in the thunder-prone northern areas of the Great Sandy Desert (see Fig. 1).

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